US Army Corps
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Walla Walla District

DRAFT

Lower Snake River Juvenile Salmon Migration Feasibility Report/ Environmental Impact Statement

APPENDIX E
Existing Systems/Major System Improvements Engineering

December 1999

FEASIBILITY STUDY DOCUMENTATION

Document Title	
Summary to the Lower Snake River Juvenile Salmon Migration Feasibility Report/Environmental Impact Statement	
Lower Snake River Juvenile Salmon Migration Feasibility Report/Environmental Impact Statement	
Appendix A	Anadromous Fish
Appendix B	Resident Fish
Appendix C	Water Quality
Appendix D	Natural River Drawdown Engineering
Appendix E	Existing Systems and Major System Improvements Engineering
Appendix F	Hydrology/Hydraulics and Sedimentation
Appendix G	Hydroregulations
Appendix H	Fluvial Geomorphology
Appendix I	Economics
Appendix J	Plan Formulation and Decision Analysis Model
Appendix K	Real Estate
Appendix L	Lower Snake River Mitigation History and Status
Appendix M	Fish and Wildlife Coordination Act Report
Appendix N	Cultural Resources
Appendix O	Public Outreach Program
Appendix P	Air Quality
Appendix Q	Tribal Consultation/Coordination
Appendix R	Historical Perspectives
Appendix S	Snake River Maps
Appendix T	Biological Assessment
Appendix U	Clean Water Act, Section 404(b)(1) Evaluation

The documents listed above, as well as supporting technical reports and other study information, are available on our website at www.nww.usace.army.mil. Copies of these documents are also available for public review at various city, county, and regional libraries.

FOREWORD

This appendix is one part of the overall effort of the U.S. Army Corps of Engineers (Corps) to prepare the Lower Snake River Juvenile Salmon Migration Feasibility Report/Environmental Impact Statement (FR/EIS).

Please note that this document is a DRAFT appendix and is subject to change and/or revision based on information received through comments, hearings, workshops, etc. After the comment period ends and hearings conclude a Final FR/EIS with Appendices is planned.

The Corps has reached out to regional stakeholders (Federal agencies, tribes, states, local governmental entities, organizations, and individuals) during the development of the FR/EIS and appendices. This effort resulted in many of these regional stakeholders providing input, comments, and even drafting work products or portions of these documents. This regional input provided the Corps with an insight and perspective not found in previous processes. A great deal of this information was subsequently included in the Draft FR/EIS and Appendices, therefore, not all the opinions and/or findings herein may reflect the official policy or position of the Corps.

STUDY OVERVIEW

Purpose and Need

Between 1991 and 1997, due to declines in abundance, the National Marine Fisheries Service (NMFS) made the following listings of Snake River salmon or steelhead under the Endangered Species Act (ESA) as amended:

- sockeye salmon (listed as endangered in 1991)
- spring/summer chinook salmon (listed as threatened in 1992)
- fall chinook salmon (listed as threatened in 1992)
- steelhead (listed as threatened in 1997)

In 1995, NMFS issued a Biological Opinion on operations of the Federal Columbia River Power System. The Biological Opinion established measures to halt and reverse the declines of these listed species. This created the need to evaluate the feasibility, design, and engineering work for these measures.

The U.S. Army Corps of Engineers (Corps) implemented a study after NMFS's Biological Opinion in 1995 of alternatives associated with lower Snake River dams and reservoirs. This study was named the Lower Snake River Juvenile Salmon Migration Feasibility Study (Feasibility Study). The specific purpose and need of the Feasibility Study is to evaluate and screen structural alternatives that may increase survival of juvenile anadromous fish through the Lower Snake River Project (which includes the four lowermost dams operated by the Corps on the Snake River—Ice Harbor, Lower Monumental, Little Goose, and Lower Granite dams) and assist in their recovery.

Development of Alternatives

The Corps completed an interim report on the Feasibility Study in December 1996. The report evaluated the feasibility of drawdown to natural river levels, spillway crest, and other improvements to existing fish passage facilities. Based in part on a screening of actions conducted in the interim report, the study now focuses on four courses of action:

- Existing conditions (currently planned fish programs)
- System improvements with maximum collection and transport of juveniles (without major system improvements such as surface bypass collectors)
- System improvements with maximum collection and transport of juveniles (with major system improvements such as surface bypass collectors)
- Dam breaching or permanent drawdown to natural river levels for all reservoirs

The results of these evaluations are presented in the combined Feasibility Report (FR) and Environmental Impact Statement (EIS). The FR/EIS provides the support for recommendations that will be made regarding decisions on future actions on the Lower Snake River Project for passage of juvenile salmonids. This appendix is a part of the FR/EIS.

Geographic Scope

The geographic area covered by the FR/EIS generally encompasses the 140-mile long lower Snake River reach between Lewiston, Idaho and the Tri-Cities in Washington. The study area does slightly vary by resource area in the FR/EIS because the affected resources have widely varying spatial characteristics throughout the lower Snake River system. For example, socioeconomic effects of a permanent drawdown could be felt throughout the whole Columbia River Basin region with the most effects taking place in the counties of southwest Washington. In contrast, effects on vegetation along the reservoirs would be confined to much smaller areas.

Identification of Alternatives

Since 1995, numerous alternatives have been identified and evaluated. Over time, the alternatives have been assigned numbers and letters that serve as unique identifiers. However, different study groups have sometimes used slightly different numbering or lettering schemes and this has lead to some confusion when viewing all the work products prepared during this long period. The primary alternatives that are carried forward in the FR/EIS currently involve four major alternatives that were derived out of three major pathways. The four alternatives are:

Alternative Name	PATH[1/] Number	Corps Number	FR/EIS Number
Existing Conditions	A-1	A-1	1
Maximum Transport of Juvenile Salmon	A-2	A-2a	2
Major System Improvements	A-2’	A-2c	3
Dam Breaching	A-3	A-3a	4

[1/] Plan for Analyzing and Testing Hypotheses

Summary of Alternatives

The **Existing Conditions Alternative** consists of continuing the fish passage facilities and project operations that were in place or under development at the time this Feasibility Study was initiated. The existing programs and plans underway would continue. Project operations, including all ancillary facilities such as fish hatcheries and Habitat Management Units (HMUs) under the Lower Snake River Fish and Wildlife Compensation Plan (Comp Plan), recreation facilities, power generation, navigation, and irrigation would remain the same unless modified through future actions. Adult and juvenile fish passage facilities would continue to operate.

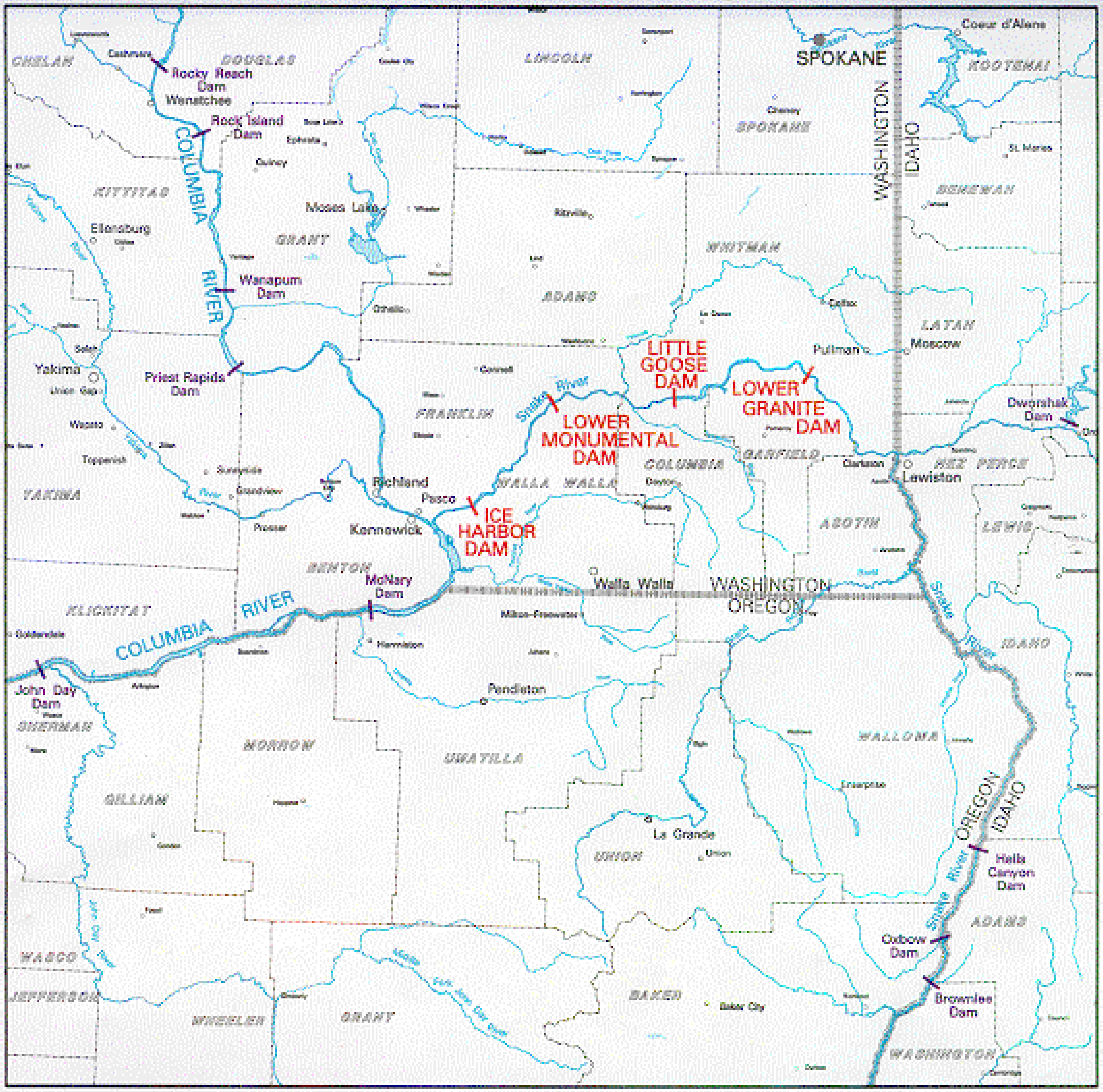
The **Maximum Transport of Juvenile Salmon Alternative** would include all of the existing or planned structural and operational configurations from the Existing Conditions Alternative. However, this alternative assumes that the juvenile fishway systems would be operated to maximize fish transport from Lower Granite, Little Goose, and Lower Monumental and that voluntary spill would not be used to bypass fish through the spillways (except at Ice Harbor). To accommodate this maximization of transport some measures would be taken to upgrade and improve fish handling facilities.

The **Major System Improvements Alternative** would provide additional improvements to what is considered under the Existing Conditions Alternative. These improvements would be focused on using surface bypass collection (SBC) facilities in conjunction with extended submersible bar screens (ESBS) and a behavioral guidance system (BGS). The intent of these facilities is to provide more effective diversion of juvenile fish away from the turbines. Under this alternative the number of fish collected and delivered to upgraded transportation facilities would be maximized at Lower Granite, the most upstream dam, where up to 90 percent of the fish would be collected and transported.

The **Dam Breaching Alternative** has been referred to as the "Drawdown Alternative" in many of the study groups since late 1996 and the resulting FR/EIS reports. These two terms essentially refer to the same set of actions. Because the term drawdown can refer to many types of drawdown, the term dam breaching was created to describe the action behind the alternative. The Dam Breaching Alternative would involve significant structural modifications at the four lower Snake River dams allowing the reservoirs to be drained and resulting in a free-flowing river that would remain unimpounded. Dam breaching would involve removing the earthen embankment sections of the four dams and then developing a channel around the powerhouses, spillways, and navigation locks. With dam breaching, the navigation locks would no longer be operational, and navigation for large commercial vessels would be eliminated. Some recreation facilities would close while others would be modified and new facilities could be built in the future. The operation and maintenance of fish hatcheries and Habitat Management Units (HMUs) would also change although the extent of change would probably be small and is not known at this time. Project development, design, and construction span a period of nine years. The first three to four years concentrate on the engineering and design processes. The embankments of the four dams are breached during two construction seasons at year 4-5 in the process. Construction work dealing with mitigation and restoration of various facilities adjacent to the reservoirs follows dam breaching for three to four years.

Authority

The four Corps dams of the lower Snake River were constructed and are operated and maintained under laws that may be grouped into three categories: 1) laws initially authorizing construction of the project, 2) laws specific to the project passed subsequent to construction, and 3) laws that generally apply to all Corps reservoirs.



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County

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GEOGRAPHIC INFORMATION SYSTEMS
Corps of Engineers
Walla Walla District

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Lower Snake River
Juvenile Salmon Migration Feasibility Study

REGIONAL BASE MAP

1999

ABSTRACT

This document is the Existing Systems and Major System Improvements Engineering Appendix. The information provided herein represents various alternatives to a drawdown of the lower Snake River. Each of the alternatives allows for the continued operation of the lower Snake River lock and dams. This appendix describes costs, engineering issues, and operations of 1) the current juvenile fish passage system, 2) alternatives available for operation of the current juvenile fish passage system, and 3) major system modifications to the current method of juvenile fish collection using surface bypass and collection technology.

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Lower Snake River Juvenile Salmon Migration Feasibility Report/ Environmental Impact Statement

Appendix E

Existing Systems and Major System Improvements Engineering

Produced by

U.S. Army Corps of Engineers

Walla Walla District

Completed October 1999
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December 1999

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FIGURES

TABLES

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ACRONYMS AND ABBREVIATIONS

AFEP	Anadromous Fish Evaluation Program
BGS	behavioral guidance structure
BO	Biological Opinion
BOR	Bureau of Reclamation
CBE	combined bypass efficiency
cfs	cubic feet per second
Corps	U.S. Army Corps of Engineers
DGAS	Dissolved Gas Abatement Study
ESA	Endangered Species Act
ESBS	extended submersible bar screen
FGE	fish guidance efficiency
FLE	fish ladder extension
FPE	fish passage efficiency
m^3/s	cubic meters per second
MOP	minimum operating pool
NMFS	National Marine Fisheries Service
O&M	operation and maintenance
PB-2A	Detailed Project Schedule
RPA	reasonable and prudent action
RSW	removable spillway weir
SBC	surface bypass collector
SES	spillway extension structure
STS	submerged traveling screens
SWI	simulated Wells Dam intake
TDG	total dissolved gas

Executive Summary

Purpose

The Walla Walla District, U.S. Army Corps of Engineers operates four lock and dam facilities on the lower Snake River. These include the Lower Granite, Little Goose, Lower Monumental, and Ice Harbor dams. In response to the National Marine Fisheries Service 1995 Biological Opinion concerning the operation of the Federal hydropower system, the Corps is studying structural and operational alternatives to improve the downstream migration of juvenile salmonids through the four lower Snake River dams. These alternatives will provide improved downstream fish migration while keeping the dams operational.

The alternatives described in this appendix may be compared to each other and to the other alternative identified for investigation under this feasibility study — permanent drawdown of the lower Snake River reservoirs.

The information contained in this appendix will be used to assist in decisions regarding future project modifications and operations of the lower Snake River system.

Fish Passage Strategies

The term “Existing System Upgrades,” as used in this appendix, refers to options available for upgrading the existing facilities used for transporting or bypassing downstream migrating juvenile fish. The term “Major System Improvements,” as used in this appendix, involves the use of surface bypass collectors and other devices to provide a way to collect fish swimming near the surface.

This appendix utilizes three different fish passage strategies in order to define and evaluate the various alternatives. These strategies include:

- In-River Passage — Keeping the fish in the river during their downstream migration.
- Transport — Collecting and transporting the fish downstream of Bonneville Dam.
- Adaptive Migration — Providing operational alternatives to allow an effective method for either in-river passage or transport.

These strategies were applied to the options for upgrading the existing facilities (Existing System Upgrades) and to the Major System Improvement alternatives. The modifications required for upgrading the existing system include the following:

- Improvement of the effectiveness of the juvenile fish bypass and collection facilities
- Additional barges for fish transportation
- Turbine modifications and improvements made during a major rehabilitation of the powerhouse
- Modification of spillways to reduce dissolved gas levels.

Major System Improvement options include upgrading the existing system, constructing surface bypass and collection (SBC) systems, and new extended submersible bar screens (ESBS) in turbine entrances.

Surface bypass and collection systems consist of surface collectors, behavioral guidance structures (BGS), and modified spillbays.

Unresolved Issues

The development of surface bypass and collection technology is still underway. As more is learned about the effectiveness of various components of surface bypass and collection systems, designs may be developed that have a higher reliability of success. These designs may differ from those presented in this appendix. However, the surface bypass and collection alternatives described in this appendix represent effective options for improving the current system of transporting and/or bypassing fish past the dams.

Some of the surface bypass and collection options include modifying a spillbay at each project. This will reduce spillway capacity by as much as 5 percent. If it is decided that a reduction in spillway capacity is not acceptable, an alternate plan to bypass fish via the central non-overflow could be implemented. Alternatively, options that would include methods to pass the 5 percent spillway capacity flow through the powerhouse and/or navigation lock during the rare flood event may be found to be feasible.

Some of the surface bypass and collection options have the potential of increasing design seismic loading on the existing dam monoliths. Further analysis is required to determine the need for measures to strengthen the structures or increase their stability.

The removable spillway weir included with SBC type 4 systems, described herein, would require model testing to determine the best shape for providing a fish-friendly bypass. Since the removable spillway weir would be resting on top of an existing spillbay, there are limitations on the possible shapes of the weir. Prototype testing would show if an acceptable design could be developed.

Several dissolved gas abatement measures are included herein. These measures include structural modifications to the spillways in an effort to reduce gas levels that are known to be harmful to fish. The improvements are based upon the latest developments in spillway deflector design and have received regional support for rapid installation. The dissolved gas abatement study (DGAS) is a system-wide study that is addressing these measures as well as more extensive measures to reduce total dissolved gas supersaturation that forms in both the Snake and Columbia rivers. However, the study is not finished. The need for these more extensive measures will be determined after completion of the system-wide study. Therefore, these more extensive gas abatement measures are not included in this appendix.

Installation of the dissolved gas abatement measures included in this appendix may impact the following: 1) adult fish passage, 2) juvenile fish passage, 3) navigation, and 4) stilling basin and channel erosion. These potential impacts must be evaluated and resolved as necessary prior to implementation of the spillway modifications.

For all alternatives other than a drawdown of the river, a portion of the fish will still be passing through the turbine environment. The Turbine Survival Program is exploring ways to improve passage through the turbines. For the purpose of this study, it was assumed that the fish passage improvements identified in the Turbine Survival Program would be applied to all turbines at the lower Snake River dams. Because of their tremendous costs, the installation of these improvements is assumed to occur during major turbine rehabilitation at that facility.

Summary

The following are summary tables for each of the Existing System Upgrades (Table ES-1) and Major System Improvement (Table ES-2) options investigated in this appendix. The summary tables include 1) costs for lock and dam operations, 2) implementation schedules, 3) fish hatchery costs, and 4) percentage of fish surviving from just upstream of Lower Granite Dam to just downstream of Bonneville Dam.

Table ES-1. Existing System Upgrades: Costs, Implementation Schedules, Hydropower Generation and Fish Survival Through the System

Option No./ Description (Spill Condition)	New Construction Costs ($Million)	Construction Implementation Schedule (Duration–Years)	AFEP Annual Costs for 27 Years ($Million)	AFEP Implementation Schedule (Duration–Years)	Lock and Dam Routine O & M and Minor Repair Annual Costs ($Million)	Major Rehabilitation of Turbines ($Million)	Major Rehabilitation of Turbines Implementation Schedule (Duration–Years)	Fish Hatcheries O&M and Minor Repair Annual Costs ($Million)	BOR Annual Costs ($Million)	Fish Survival Through the System (%)
A-1 Adaptive Management Strategy (Voluntary Spill)	89.3	5	5.3	27	30.7	193.6	41	14.5	2.3	83.38
A-1a In-River (Voluntary Spill)	80.1	5	5.3	27	30.5	193.6	41	14.5	2.3	54.94
A-2a Transport (No Voluntary Spill except Ice Harbor)	67.9	5	3.6	27	30.7	193.6	41	14.5	2.3	93.11

Notes: AFEP = Anadromous Fish Evaluation Program
O & M = Operation and Maintenance
MW-hr = Megawatts per hour
BOR = Bureau of Reclamation

Table ES-2. Major System Improvements: Costs, Implementation Schedules, Hydropower Generation and Fish Survival Through the System

Option No./ Description (Spill Condition)	New Construction Costs ($Million)	Construction Implementation Schedule (Duration–Years)	AFEP Annual Costs for 27 Years ($Million)	AFEP Implementation Schedule (Duration–Years)	Lock and Dam Routine O & M and Minor Repair Annual Costs ($Million)	Major Rehabilitation of Turbines ($Million)	Major Rehabilitation of Turbines Implementation Schedule (Duration–Years)	Fish Hatcheries O&M and Minor Repair Annual Costs ($Million)	BOR Annual Costs ($Million)	Fish Survival Through the System (%)
A-2b Transport (High Cost–No Voluntary Spill)	270.0	11	7.4	27	32.2	193.6	41	14.5	2.3	95.45
A-2c Transport (Low Cost–No Voluntary Spill except Ice Harbor)	162.5	7	5.7	27	31.3	193.6	41	14.5	2.3	95.41
A-2d Adaptive Management Strategy (Voluntary Spill varies)	297.3	11	9.5	27	31.3	193.6	41	14.5	2.3	89.08
A-6a In-River (Voluntary Spill and No BGS, Higher Flow Augmentation)	316.7	10	9.2	27	30.3	193.6	41	14.5	22.8 annual cost plus $160.5 for first 10 years	65.87
A-6b In-River (Voluntary Spill and No BGS, No Flow Augmentation)	316.7	10	9.2	27	30.3	193.6	41	14.5	2.3	Not Available
A-6d In-River (Voluntary Spill only at Little Goose, BGS at other dams)	249.2	10	9.0	27	29.9	193.6	41	14.5	2.3	Not Available

Notes:
AFEP = Anadromous Fish Evaluation Program
O & M = Operation and Maintenance
MW-hr = Megawatts per hour
BOR = Bureau of Reclamation

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1. Introduction

1.1 General

The Walla Walla District of the U.S. Army Corps of Engineers (Corps) operates four lock and dam projects on the lower Snake River, including Lower Granite, Little Goose, Lower Monumental, and Ice Harbor. In response to the National Marine Fisheries Service 1995 Biological Opinion concerning the operation of the Federal Columbia River Power System, the Corps is studying structural and operational alternatives to improve the downstream migration of juvenile salmon smolts through the four lower Snake River dams.

For the lower Snake River Juvenile Salmon Migration Feasibility Study (Feasibility Study), three alternatives are being studied: 1) Existing System Upgrades, 2) Major System Improvements, and 3) Natural River Drawdown. Evaluations of Existing System Upgrades and Major System Improvements are summarized in this appendix while Natural River Drawdown (i.e., breaching the four lower Snake River dams) are addressed in Appendix D.

Existing System Upgrades not only covers facilities and project operations as they currently exist and are operated at the dams and reservoirs, but also includes measures to maintain or upgrade present facilities to state-of-the art design and operation. Depending on the juvenile fish passage strategy (see Section 1.3), this may or may not require voluntary spill. A full discussion of Existing System Upgrades involving dissolved gas, turbines, and other miscellaneous measures is provided in Annexes A, C, and D, respectively.

Major System Improvements includes upgrades to the existing systems plus major system modifications that significantly impact project layout and operations. This includes utilizing surface bypass and collection technology to safely collect and guide fish. Depending on the alternative, voluntary spill may or may not be required. A full discussion of surface collection systems included with Major System Improvements options can be found in Annex B.

1.2 Purpose

This document presents key engineering and cost information concerning the Existing System Upgrades and Major System Improvement alternatives. In addition, it summarizes biological performance information gathered during prototype testing of surface collector concepts and predicted biological performance data for each of the alternatives included in this appendix. This information will be used in the Feasibility Study where recommendations regarding future project modifications and operations of the lower Snake River system will be made.

1.3 Juvenile Fish Passage Strategies

Existing System Upgrades and Major System Improvements are described in the context of three strategies for aiding in the downstream migration of juvenile fish safely past the dams: 1) In-River Bypass, 2) Transport, and 3) Adaptive Migration Strategy.

In-River Bypass refers to designs and operations that would bypass fish directly to the tailrace via existing spillways or through some type of fish bypass system. No trucking or barging of fish would be done. Based on current project operations, this system would require voluntary spill.

Transport refers to directing fish to a truck or barge transport system with capabilities to bypass fish to the tailrace in an emergency. This system would generally not require voluntary spill.

The Adaptive Migration Strategy would optimize current operational objectives where either in-river or transport strategies can be used. This strategy addresses concerns about the risks and effectiveness associated with bypass only and transport only. The combined overall strategy would be to operate the different facilities so that a spread-the-risk philosophy could be implemented considering the whole river system. This strategy might be used over a relatively short time period (5 to 10 years) until a regional decision is made to select either a transport or in-river passage strategy. The Adaptive Migration Strategy might also be a long-term plan, where transport may be used at certain times and in-river bypass used at other times, depending on varying river conditions. This type of operation may include voluntary spill, depending on whether the fish are kept in the river or transported. Because of its operational flexibility, the Adaptive Migration Strategy is more effective at addressing doubts as to whether fish transportation is better or worse for fish than in-river passage.

1.4 Spill Operations

In this appendix, “voluntary spill” is defined as spill intended to attract juvenile fish to the spillways for in-river passage. Typically, this spill would not have taken place under normal project operations. “Involuntary spill” is defined as spill that is required to pass high river discharge past the project once powerhouse capacities/power requirements have been reached.

As described in the Fish Passage Plan for Corps of Engineers Projects (March 1998), the Corps shall spill for juvenile fish passage according to the NMFS Biological Opinion. As it relates to the lower Snake River dams, during the juvenile spring/summer chinook migration season (April 10 through June 20), the Corps is to spill at all dams (except under certain exceptions) to the gas cap, which has been defined as 120 percent total dissolved gas (TDG) supersaturation. Voluntary spill levels are limited by the resulting TDG levels. If the TDG levels are high enough and fish are exposed to these levels long enough, both adult and juvenile migrants would be harmed.

The decision to include voluntary spill as a portion of any Major System Improvement alternative will depend upon the ability of voluntary spill to help achieve the goals of that alternative.

1.5 Annexes

Annexes to this appendix are included at the back of the appendix. These annexes provide detailed backup information used to develop the main body of the appendix. The reader may wish to refer to the annexes for detailed information not included in the main body of the appendix. The annexes include descriptions of:

- Existing system operations (including proposed upgrades to the existing system)
- Surface bypass and collection alternatives
- Dissolved gas abatement measures
- Turbine Survival Program
- Cost and implementation schedules.

2. Background

2.1 General

On March 2, 1995, the National Marine Fisheries (NMFS) issued a Biological Opinion (BO) for the Reinitiation of Consultation on 1994-1998 Operation of the Federal Columbia River Power System and Juvenile Transportation Program in 1995 and Future Years (NMFS, 1995a). The BO established immediate measures necessary for the survival and recovery of Snake River salmon stocks listed under the Endangered Species Act (ESA). In response to the BO, the Corps has been investigating various system improvements to the lower Snake River dams intended to improve the effectiveness of downstream smolt migration. These system improvements represent an alternative to a drawdown of the lower Snake River dams.

2.2 Existing Juvenile Fish System

Since the construction of each of the lower Snake River dams, the Corps has operated adult fish collection and passage facilities at each dam. These facilities were developed in collaboration with the regional fishery agencies to aid in the upstream migration of adult fish. Juvenile fish bypass facilities were developed or installed as the four lower Snake River dams were constructed. Facilities were upgraded as new technology developed.

2.3 Development of Surface Bypass and Collection Technology

The Corps of Engineers has focused much attention on the development of surface bypass and collection system (SBC) options. These options are intended to collect downstream migrating smolts in the forebay and safely bypass them across the dam (in-river options) or transport them downstream in trucks or barges (transportation option). Objectives for developing SBC systems include: 1) increasing the number of juvenile fish guided for bypass or collection through non-turbine routes; 2) reducing fish stress, injury, and migration delays; and 3) reducing high-spill levels that are associated with dissolved gas problems and lost power generation.

Brainstorming sessions were held in Walla Walla in July 1994 in order to develop and expand surface bypass and collection concepts. Participants in these meetings included private individuals; consulting firm representatives; and state, Federal, and tribal fishery representatives. A prototype surface collector was constructed in 1996 at Lower Granite Dam. The basis for this design was the successful surface-oriented bypass system currently in use at Wells Dam on the mid-Columbia River. Biological performance data of the Lower Granite prototype was collected and evaluated. Modifications were made in 1998 to the Lower Granite prototype to effectively make the collector deeper and to include a behavioral guidance structure to guide fish to the SBC entrance. More testing is now underway. A more detailed discussion of the SBC prototype testing is included is Section 4.4 of this appendix.

Preliminary hydraulic model testing of methods for removing most of the water entering the SBC has been completed. Dewatering to a lower flow rate is required for SBCs that allow for fish transportation because the downstream juvenile fish facility cannot handle the large flows used in surface collection. Results of the SBC testing and dewatering modeling have been encouraging. Therefore, further development of SBC options is ongoing.

2.4 Conceptual Level SBC Designs

The Corps contracted the development of concept level SBC designs for the lower Snake River dams based on the fundamental surface collector concepts being tested at Lower Granite Dam. This effort focused on the development of SBC designs and costs while the prototype testing at Lower Granite was used for evaluating SBC performance.

Once the prototype testing had provided preliminary performance levels for the various concepts and the engineering report had verified feasibility and cost, it was necessary to define combinations of measures that would most reasonably meet the goals of the fish passage strategies (in-river passage, transportation, adaptive migration). A second report was developed investigating various SBC system combinations (refer to Annex B). These alternative combinations are represented in Tables 1 and 2 in the Executive Summary and are more fully described later in this appendix and in Annex B.

2.5 Dissolved Gas Abatement Study (DGAS)

Currently, the Corps is actively involved in the development of methods reducing total dissolved gas (TDG) supersaturation in the lower Snake and Columbia River systems. High levels of TDG supersaturation are known to be harmful to fish. The DGAS does not involve separate investigations of the Snake and Columbia rivers. Instead, the DGAS treats the TDG supersaturation as a system-wide problem. To date, the study has included a Phase I technical report that recommended five DGAS options for further investigation. A Phase II report is currently being developed that investigates several additional alternatives. However, the report is not scheduled for completion until fiscal year 2000.

2.6 Coordination

The Corps coordinated with a large number of fish agencies throughout the northwest and local interest groups in the development of the SBC combinations report and the Dissolved Gas Abatement Study. For more detailed information, refer to the annexes at the back of this appendix.

3. Existing System Features

The “Existing System” is defined for this appendix as project features and operations that presently are considered to aid in the migration of juvenile and adult fish on the lower Snake River. Major existing system components are listed below.

- Adult Fish Passage Systems: Includes fish ladders, pumped attraction water supplies, and powerhouse fish collection systems designed to aid upstream migrating adult fish.
- Juvenile Fish Bypass and Collection Systems: Includes turbine intake screen systems.
- Juvenile bypass and collection facilities and transportation facilities intended to aid downstream migrating fish.
- Minimum Operating Pools (MOP): Includes operating the reservoirs at minimum operating pool elevation during the juvenile fish outmigration.
- Turbine Operations: Includes operating the turbines within 1 percent of peak efficiency.
- Spill Operations: Includes voluntary spill to assist in the bypassing of juvenile salmon and steelhead in accordance with the Biological Opinion. The spill is thought to attract the fish away from the turbines, and towards the spillway.
- Flow Augmentation: Includes the use of upstream storage for flow augmentation. Flow augmentation decreases the duration of downstream migration.
- Spillway Gas Control Measures: Includes the use of spill deflectors to allow an increase in spill flows without exceeding the mandated 120 percent total dissolved gas supersaturation limits.
- Spillway Gas Monitoring: Continued monitoring and control of total dissolved gas levels in order to ensure compliance with state standards.
- Fish Hatcheries: Continued operation and maintenance of fish hatcheries.
- Anadromous Fish Evaluation Program (AFEP): Involves biological evaluations of anadromous fish and evaluations of proposed dam modifications to predict resulting impacts to fish.

Refer to Annex A for more detailed information, including the current operations per the 1995 Biological Opinion.

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4. Future Development

4.1 Introduction

Measures that have a high potential of increasing the effectiveness and efficiency of getting fish past the dams are discussed below. These measures are combined to form the Existing System Upgrade options (see Section 5) and Major System Improvement Options (see Section 6). The information presented in Sections 4.2 and 4.3 provides an overview of key measures that could be used as part of either existing system upgrades or major system improvements.

4.2 Dissolved Gas Abatement Measures

4.2.1 General

A Dissolved Gas Abatement Study (DGAS) was initiated in 1994 to examine potential methods of reducing TDG produced by spillway operations at the Corp's eight dams on the lower Snake and Columbia rivers. The study was called for by the National Marine Fisheries Service (NMFS) Biological Opinion on Operation of the Federal Columbia River Power System (1995). NMFS prescribed two reasonable and prudent measures (RPA 16 and 18) that directed the Corps to address means to measure, evaluate, and prescribe alternatives to reduce total dissolved gas (TDG) in the lower Snake and Columbia rivers.

The DGAS is being completed in two parts: a Phase I reconnaissance-level report and a Phase II feasibility-level report. The Phase I report was completed in April 1996. The Phase II report is scheduled for completion in fiscal year 2000.

The Phase I report recommended several measures which could be implemented quickly to provide immediate reductions in TDG production. These measures included spillway operational changes and design and construction of spillway deflectors at Ice Harbor and John Day dams. These measures have been implemented and the associated benefits were observed during the spring of 1998.

The Phase II DGAS studies are ongoing. Numerous structural measures that hold potential for reducing TDG production have been identified and the engineering evaluation is nearing completion. Biological evaluations have yet to be completed. The system-wide analysis contained in the Phase II report is scheduled for completion within the next two years. The Phase II effort and descriptions of the measures which could be implemented at the lower Snake River dams are summarized in Annex C of this appendix.

Various gas abatement improvements are described in this appendix. These DGAS measures will provide water quality benefits by reducing TDG production at the lower Snake River dams. The first DGAS measure described below includes installation of end bay deflectors. This has been proven to be a significant benefit for gas abatement at a relatively low cost. This proposed improvement has received considerable regional support and has been made a part of all alternatives described in this appendix.

The second group of DGAS options described below includes various modifications of the existing deflectors and installation of new pier extensions.

A third level of gas abatement protection may be provided by use of one or more of the major gas improvement measures defined within the gas abatement annex (Annex C). Since a decision on these measures will not be made until after the Phase II report is complete, none of the alternatives in the Feasibility Report will initially have this third level of protection.

The measures described below would be designed to minimize the production of TDG through a range of normal flows under current operating conditions. These would reduce the TDG concentrations resulting from current spill levels. Also, the gas abatement measures would provide the ability to increase spill volumes for fish passage, without exceeding the 120 percent TDG supersaturation level spill cap included in the 1995 Biological Opinion. Other identified measures could eventually be recommended following the system-wide analysis. Refer to Annex C for a more complete description of all the DGAS alternatives.

4.2.2 Additional End Bay Spillway Deflectors

Spillway flow deflectors have been installed at all four of the lower Snake River dams (Table 4-1). Deflectors consist of a horizontal lip 2.4 to 3.8 meter (8.0 to 12.5 feet) long placed on the spillway ogee section just below or near the minimum tailwater elevation. “Ogee” refers to the reverse curve shape of the spillway. The deflectors produce a thin discharge jet that skims the water surface of the stilling basin. Though the skimming flow is highly aerated, spillway discharge is prevented from plunging and entraining air deep into the stilling basin. Reducing the depth of plunge, and thus the hydrostatic pressures acting on the aerated flow, reduces the production of TDGs.

Table 4-1. Existing Deflectors

Dam	No. of Spillway Bays	No. of Deflectors	Deflector Elevation (meters)	Deflector Length (meters)	Deflector Transition (meters)
Ice Harbor	10	8	103.0 (338.0)	3.81 (12.5)	4.57 (15.0) radius
Ice Harbor	10	2	101.8 (334.0)	3.81 (12.5)	4.57 (15.0) radius
Lower Monumental	8	6	132.2 (434.0)	3.81 (12.5)	Flat
Little Goose	8	6	162.2 (532.0)	2.44 (8.0)	Flat
Lower Granite	8	8	192.0 (630.0)	3.81 (12.5)	4.57 (15.0) radius

NOTE: feet in parentheses (feet)

Deflectors have lowered the levels of dissolved gasses generated by conventional spillways by as much as 15 to 20 percent TDG. The construction of additional flow deflectors on non-deflected spillway bays will further reduce TDG production.

The effectiveness of spillway flow deflectors is dependent upon the geometry of the deflector, spillway discharge, and deflector submergence (tailwater elevation minus deflector elevation). Performance is optimized when the elevation of the deflector, associated with a design discharge and tailwater elevation, is set to provide a smooth skimming flow. If the tailwater elevation relative to the deflector is too low, the deflected discharge generates a plunging flow, subjecting aerated flow to higher pressures. If the tailwater elevation is too high, the deflected discharge generates a highly aerated undular flow that will also draw air deep into the basin.

Additional spillway flow deflectors can be installed at some of the lower Snake River dams. The benefit of added deflectors is dependent on the hydraulic performance of the deflector and the ratio of deflected to non-deflected spill flow. Spill patterns developed for each project establish the distribution of spill through deflected and non-deflected spillway bays and influence the generation of TDG. They are designed to maintain acceptable tailrace conditions for adult salmonids seeking upstream passage and juvenile salmonids migrating downstream, and are included in the Corps of Engineers' annual fish passage plan.

Both Lower Monumental and Little Goose spillways have deflectors on six of the eight spillway bays. Thus, these are the only two facilities with the potential for adding end bay deflectors. Deflectors were not constructed in spillway bays 1 and 8 on these projects because of adult fish passage concerns. Recent studies indicate adult passage rates may not be as sensitive to deflected flow conditions as previously expected. Adding end bay deflectors may further reduce the saturation of TDGs without adverse impacts to adult passage.

4.2.2.1 Design

End bay spillway flow deflectors at Lower Monumental and Little Goose dams would be designed to provide optimum skimming flow conditions for spillway flows up to 283.2 cubic meters per second (m^3/s) (10,000 cfs) per bay and tailwater elevations up to 135.3 meter (444.0 feet) at Lower Monumental and 165.2 meter (542.0 feet) at Little Goose. Based on the performance of the Ice Harbor deflectors and current project operating conditions, deflectors in spillway bays 1 and 8 would be 3.81 meter (12.5 feet) long with a 1.2 meter (15 feet) radius fillet between the sloped face of the spillway and the horizontal surface of the deflector. The two additional deflectors would include pier nose extensions and would be set at elevation 131.0 meter (430.0 feet) at Lower Monumental and 161.2 meter (529.0 feet) at Little Goose, 1.2 meter (4.0 feet) lower than the existing deflectors. At this elevation the deflectors should provide optimum hydraulic performance for voluntary fish passage spills up to the 120 percent TDG spill levels, which may range from 198.2 to 283.2 m^3/s (7,000 to 10,000 cfs) per bay.

Sectional spillway and general model studies will be required to verify the final deflector design. The influence of the lower deflectors on stilling basin performance and potential impacts to tailrace and stilling basin erosion must be carefully evaluated. Consideration must also be given to adult fish passage and the influence of the flow deflectors on fishway entrance conditions.

4.2.2.2 Total Dissolved Gas Performance

For Lower Monumental, TDG levels of 120 percent are generated with a uniform spill release of 203 m^3/s (7,170 cfs) through each of the six bays with deflectors for a total of 1,218 m^3/s (43,000 cfs). If the two end bay deflectors are constructed and perform similar to the Ice Harbor deflectors, the 120 percent TDG spill cap may increase by 198 to 283 m^3/s (7,000 to 10,000 cfs) per end bay, potentially raising the total 120 percent TDG discharge to between 1,721 and 1,892 m^3/s (60,800 to 66,800 cfs).

For Little Goose, TDG levels of 120 percent are generated with a uniform spill release of 227 m^3/s (8,000 cfs) through each of the six spill bays with deflectors. This is a total for the dam of 1,359 m^3/s (48,000 cfs). If the two end bay deflectors are constructed and perform similar to the Ice Harbor deflectors, the 120 percent TDG spill cap may increase by 198 to 283 m^3/s (7,000 to 10,000 cfs) per end bay. This may potentially raise the total 120 percent TDG discharge to 1,841 m^3/s (65,000 cfs).

4.2.2.3 Operations

If properly designed, end bay deflectors should have no impact on project operations except that they will allow additional spill volumes before the tailrace exceeds the 120 percent TDG cap. This may reduce the amount of water available to pass through the existing powerhouse resulting in reduced power generation.

4.2.3 Modified Deflectors

The effectiveness of a flow deflector will improve if it can be designed to perform over a wider range of spill discharge and tailwater fluctuations. The ideal deflector generates a smooth, stable skimming flow across the water surface of the stilling basin. However, the existing deflectors were designed to perform within a narrow range of tailwater elevations and spill discharges. The deflectors recently constructed at Ice Harbor and John Day appear to perform better than deflectors at other projects in terms of gas production versus spill discharge. The new deflectors are 3.81 meter (12.5 feet) long with a 4.6 meter (15 feet) radius transition and are set at an elevation that provides optimal performance during the more typical project operations under the current voluntary spill program. The pier walls between spillway bays at Ice Harbor and John Day were also extended to the end of the deflectors. Deflectors at other projects may be modified to perform more like the new John Day and Ice Harbor spillway deflectors. These modifications are relatively inexpensive and could reduce gas levels by a few percentage points.

With the exception of Ice Harbor, current operations at the lower Snake River dams are different from those at the time of the original deflector installation. Projects typically operate at minimum pool elevations as required by the 1995 Biological Opinion. Voluntary spill resulting in 120 percent TDG supersaturation is mandated for aiding fish passage. Turbine discharges are limited to operations within the peak one percent of efficiency, limiting the total powerhouse discharge to less than 3,400 m^3/s (120,000 cfs). Each of these operational measures cause the deflectors to function over a range of tailwater elevations lower than that used for the original design.

The new spillway flow deflectors at John Day and Ice Harbor dams were constructed with a 4.6 meter (15-feet) radius transition (fillet) from the spillway ogee to the horizontal surface of the deflector. Lower Granite was also constructed with a 4.6 meter (15-feet) radius and the Bonneville deflectors have a 1.8 meter (6-feet) radius fillet. The deflectors at Little Goose and McNary Dams do not have a radius fillet. Two deflectors at Lower Monumental have a radius fillet. Model studies and prototype evaluations indicate deflectors with a radius transition generate a smoother and more stable surface jet.

Pier extensions were added at both John Day and Ice Harbor. The pier extensions extend the downstream face of the existing piers flush to the downstream edge of the flow deflector. The pier extensions prevent the sidewall flow from directly impacting the flow deflector and plunging into the basin. The sidewall flow rises from the corners of the spillway gates and rides 1.8 to 2.4 meter (6 to 8 feet) above the surface of the spillway discharge jet. As the sidewall flow reaches the end of the pier walls it expands abruptly. The two jets, one from each side of the wall, converge. The lower portion of the combined jet impacts the exposed section of the deflector immediately below the pier. The upper portion reaches beyond the deflector and plunges into the stilling basin. The extension forces the expansion of sidewall flow to occur further out away from the deflector, where the flow becomes intercepted by the much more dominant deflected surface flow, preventing it from plunging into the basin. The hydraulic performance of pier extensions has been observed in the spillway sectional models of John Day and Ice Harbor, as well as the prototype structures. Though both John Day and Ice Harbor deflectors provide excellent gas reduction benefits, it is difficult to determine the overall influence of the pier extension on the TDG performance of those deflectors. However, it is reasonable to expect that by preventing the sidewall flow from entraining air and plunging deep into the stilling basin, the generation of total dissolved gasses will be reduced. In addition to reducing the plunging and aeration of flow, the pier walls were recommended to prevent fish, which may be entrained within the lower portion of the sidewall flow, from directly impacting the exposed section of the spillway flow deflector.

The TDG reduction performance of deflectors set too high or too low, because of outdated operations, may be improved by raising or lowering them accordingly. Project-specific operations for a design range of total river flows must be established to optimize the deflector elevation. Given the percent spill requirement and design range of total river flow, the tail water elevations and unit spill discharges are easily identified. The ideal submergence and deflector elevation can then be determined from physical spillway model studies and prototype evaluations.

4.2.3.1 Design

Deflector modifications could include pier nose extensions, construction of a smooth radius transition, and reconstruction of the deflector at an optimum elevation. Based on the performance of the Ice Harbor deflectors and current project operating conditions, the modified deflectors would be 3.8 meters (12.5-feet) long with a 4.6-meter (15-foot) radius transition from the sloped face of the spillway to the horizontal surface of the deflector. The new or reconstructed deflectors would be constructed at an elevation providing optimum hydraulic performance for voluntary fish passage spills up to the 120 percent TDG spill levels.

Lowering the existing deflectors would require removal of much of the deflector concrete and reinforcement steel, making it more feasible to remove the entire deflector and construct all new deflectors. However, if the deflectors are not lowered, the radius transitions and pier extensions could possibly be constructed without demolishing the existing deflectors, resulting in a significant cost savings.

4.2.3.2 Total Dissolved Gas Performance

The incremental gas abatement improvements of each potential modification are difficult to estimate. Design improvements similar to those implemented at Ice Harbor should produce similar reductions in TDG levels. However, the Ice Harbor tailrace channel is significantly shallower than the Lower Monumental channel. The shallower channel alone may account for gas reduction levels of 2 to 4 percent. It is possible that only a 1 to 2 percent reduction in gas levels may be realized at each dam due to the radius transitions, pier nose extensions, and optimization of the deflector elevation.

4.2.3.3 Operations

Modification of existing deflectors and/or construction of new deflectors will not significantly change or impact project operations. However, the improved deflectors will increase the spill required to reach the 120 percent TDG supersaturation spill cap. Increasing spill will reduce the amount of water available for hydroelectric energy production.

4.3 Turbine Measures

4.3.1 General

Under present conditions, direct fish survival through a typical lower Snake River turbine ranges from 89 to 94 percent. Unless the natural river drawdown alternative is selected, it is likely that all of these units will require major repair or rehabilitation in the next 10 to 50 years. The Turbine Passage Survival Program is currently gathering information that will allow an accurate evaluation of fish passage benefits associated with turbine operational changes and changes resulting from the incorporation of improved fish passage turbine design concepts. For the purpose of this appendix, it is assumed that the information from the Turbine Passage Survival Program will be incorporated into the operation and design of the rehabilitated units. The benefits to anadromous fish stocks are potentially significant and cannot be ignored, since they will accrue over the life of a rehabilitated turbine, which is estimated to be 35 to 50 years. An approximate schedule for these rehabilitations is given in Annex D.

4.3.2 Improved Turbine Operation (3-D Cams)

The most significant improvement in operation will result from optimizing performance of the turbine units with fish diversion devices installed in the unit. The installation of these devices, including fish screens and surface collection structures, can affect turbine operational efficiency by 1 to 3 percent. Through the use of turbine performance models, new flow measurement technology developed in the Turbine Passage Survival Program, and prototype tests, new optimized turbine performance curves with installed fish diversion devices will be developed. The performance curves relate power output to differential head, flow rates, wicket gate openings, and blade angles. 3-D cams are computer software based upon the turbine performance curves that automatically adjusts the wicket gate openings and turbine blade angle to optimize turbine efficiency. It is widely thought that the stress on fish passing through the turbines is minimized if the turbines are operating at peak efficiency. Therefore, use of the 3D-cams should maximize hydroelectric production efficiency and reduce impacts to fish passing through the turbines.

4.3.3 Other Turbine Improvements

Improvements to turbine passage may be accomplished by modifying the major features of the turbine. Modifications include the following: 1) runner redesign, 2) reorientation of the wicket gate and stay vanes, 3) use of smooth coatings, 4) minimizing gaps, 5) reshaping of the hydraulic transitions or surfaces, and 6) extension of the draft tube. Results from the Turbine Passage Survival Program will be used to decide which of these measures will yield significant improvements to fish passage through the turbines. For estimating purposes, it was assumed that the cost for all items included in this paragraph was developed from the costs included in the Ice Harbor Powerhouse Major Rehabilitation Program Report, dated March 1997. As the Turbine Passage Survival Program proceeds, the necessary improvements will be better defined.

4.4 Surface Bypass and Collection (SBC) Measures

4.4.1 General

SBC measures will improve fish passage conditions by taking advantage of the tendency for juvenile fish to stay in the upper portions of the water column. SBC designs are based on passive fish behavior. Passive fish behavior refers to allowing fish to maintain their natural preferences for horizontal and vertical surface-oriented distribution. As it compares to existing systems, justification for developing SBC systems relates to the following: 1) increasing the number of juvenile fish guided for bypass or collection through non-turbine routes, 2) reducing fish stress, injury, and migration delays, 3) reducing high-spill levels that are associated with dissolved gas problems, and 4) losing power generation. For total system designs, final SBC systems have to consider surface collection, fish bypass/transport, and river outfall components. Refer to Annex B for more detailed information on SBC technology and conceptual designs.

The Corps began brainstorming sessions in July 1994 (receiving input from consultants, fishery agencies, and tribes) and has proceeded with SBC prototype development at several dams. Concepts discussed and being evaluated consist of a variety of both fixed and floating systems used either alone or combined with fish guidance devices (physical and/or behavioral), project operational changes, with and without fish sampling, and with and without transport, etc. Biological and environmental considerations, as well as construction, operational, cost, and schedule elements, all factor into developing realistic surface oriented fishways that would have a high potential of improving passage and survival of juvenile fish migrating past Corps' Snake and Columbia River hydroelectric projects. Immediate SBC objectives have been to collect information on SBC performance, designs, and costs to be used as a basis for comparing SBC systems with other options for improving fish survival in the Lower Snake River Feasibility Study. Future efforts may include continued development and investigation of SBC concepts that appear promising.

The original concept of SBC is founded largely on the successful implementation of 12 years of research and development of a system at Wells Dam on the mid-Columbia River. However, since there are major differences between Corps' projects and the Wells hydrocombine design (as well as differences between Corps' projects themselves), each project design will be site-specific.

4.4.2 Technology Overview

The SBC systems are designed to provide benign, fish-friendly, surface-oriented passage systems that juvenile fish, already distributed high in the water column, can use to pass a dam safely. An example of a highly successful, surface-oriented bypass system currently in use is at Wells Dam on the mid-Columbia River. The Wells Dam system (with its hydrocombine design) is different from any SBC system that might be developed for lower Snake River projects. However, lessons are being learned from the surface bypass efforts at Wells Dam, as well as ongoing SBC work at other projects in the region. Effectiveness and appearance of these designs would vary from project to project on the lower Snake River.

The premise behind the SBC designs is that fish located upstream of a dam generally tend to follow bulk flow into the project. A key assumption of SBC systems is that, even if there are high bulk flows going to deep powerhouse intakes or deep spillway gate openings, fish tend to stay surface oriented (if given the opportunity) and pass through a system at shallower depths. There are several factors that are believed to influence the effectiveness of SBC systems besides bulk flow influences. The factors include the depth of fish in the water column, flownets produced by SBC structures as they relate to turbine and spillway hydraulics, opportunity of discovery for fish to find an SBC fishway entrance prior to using a turbine or spillway flow passage, and SBC fishway entrance conditions (total volume, velocities, horizontal/vertical orientations, etc.).

In the case of a powerhouse-related SBC component with fishway entrance slots (as demonstrated by Wells Dam and by SBC prototype designs at other projects, including the Lower Granite prototype tests), fish will enter SBC fishway entrances with different levels of success if given the option to take this higher passage route. Changes in the 1998 Lower Granite prototype SBC structure incorporated a simulated Wells Dam intake (SWI) design. This SWI design effectively makes the SBC structure deeper and influences flow lines approaching the SBC structure to allow fish a greater chance to discover SBC entrances prior to passing towards the turbine intakes.

The design of a behavioral guidance structure (BGS)-related SBC component is based on the observation that fish tend to guide along physical structures that are generally lined up with river flow. One example of this is at Rocky Reach Dam on the mid-Columbia River where fish follow surface flows passing by operating generating units to congregate in a cul-de-sac at the end of the powerhouse. Another example is at Lower Granite where fish have guided along a relatively shallow trash shear boom. The BGS prototype test design at Lower Granite utilizes this same principle but exaggerates the differences between deep powerhouse intakes and surface-oriented guidance systems. It is believed that a combination of a general, downstream angled flow approach in the forebay, a deep physical barrier with relatively low velocities passing beneath the structure, and strong SBC fishway entrance surface flows at the downstream end of the BGS should provide for passive fish movement toward the entrance.

The Corps and others in the region have been involved in accelerated programs to develop and evaluate different variations of SBC technology for different locations. There are no established criteria for SBC system designs. Preliminary SBC design criteria (fishway entrance configurations, flow requirements, number of fishway slots, structure depths, and water velocities below the BGS, etc.) used as part of the SBC Conceptual Design Report for different design options were developed by the collective judgment of biologists and engineers (Corps and non-Corps personnel). As SBC prototype test results from different test efforts become available, future reevaluation and refinement of SBC designs, as presented in the feasibility study, will be required prior to installation of final SBC systems at the different lower Snake River projects. Additional work, focusing on other projects besides Lower Granite, might include activities such as baseline fish behavior data collection, hydraulic model studies, and site-specific prototype work.

4.4.3 SBC System Types

4.4.3.1 General

SBC concepts discussed and evaluated in a preliminary SBC conceptual design report consisted of a variety of both fixed and floating systems, used either alone or in combination with fish guidance devices, project operational changes, with and without transport, etc., at Lower Granite. This conceptual design report was used as the basis for the SBC Combinations report (See Annex B). A few of the SBC concept options utilized a BGS to guide fish to the spillway or smaller surface collectors. Also, some of the options included a 21.3-meter (70-foot) deep surface collector, while other options included 16.7-meter (55-foot) deep surface collectors. Biological and environmental considerations, as well as construction, operational, cost, and schedule elements, all factored into developing realistic, surface-oriented fishways. These designs were used as the basis for the system combination designs.

In the preliminary SBC conceptual design report, ten individual SBC design options for Lower Granite were developed and evaluated. Each of these SBC options was made up of components which worked together to achieve a specific bypass strategy. Some of these components have been tested at the Lower Granite SBC prototype to determine their biological effectiveness, either individually or in combination with each other. Based on the information in the conceptual design report and results of the prototype testing, four of the ten options evaluated were selected for continued study in the SBC System Combinations Report. This report uses these SBC design types to create the river system combinations.

4.4.3.2 Designs and Operations

General

Each of the Major System Improvement options utilizing SBC system combinations use one or more of four SBC type designs. (See Annex B for a more detailed explanation of why these four SBC combinations were selected). These designs are combined at the different projects in such a way as to achieve the overall migration strategies for the river, as discussed in Sections 1.3 and 1.4. In some instances, a particular project would not utilize any of these SBC types. Instead, it would use either existing or new ESBS intake diversion systems only.

The four SBC designs are as follows:

- Full-length SBC powerhouse channel with dewatering (Type 1)
- Full-length SBC powerhouse channel bypass without dewatering (Type 2)
- Two-unit SBC powerhouse channel and BGS system, with Dual Passage Options (Type 3)
- Modified SBC spillway bypass (Type 4).

Each one of these SBC design types would look slightly different, depending on which project it would be applied at. For illustration purposes, SBC Type 1, 2, and 3 designs, as they would typically be applied at a lower Snake River dam, are presented below for Lower Granite Dam (Figures 4-1, 4-2, and 4-3, respectively). The SBC Type 4, as it would typically be applied at a lower Snake River dam, is presented below for Ice Harbor Dam (Figure 4-4).

Type 1 - Full Length SBC Powerhouse Channel with Dewatering

Overview

The design goal of SBC Type 1 is to provide a surface collector system designed to attract fish away from the turbine intakes across the face of the entire powerhouse. The fish would be directed to the existing juvenile fish bypass gallery inside the dam where they would swim downstream to the juvenile facilities. The design allows for the channel to be used in conjunction with extended submerged bar screen (ESBS) intake diversion screens. Adequate dewatering of the fish-bearing transport flow is provided in the channel so that the fish entering the SBC can be delivered to the existing juvenile fish gallery inside the dam, where they would be combined with the fish diverted by the intake diversion screens. The gallery is designed to deliver the fish to the fish-handling and transport/release facilities downstream. In addition, in case there is a problem with the dewatering portion of the channel, the design will allow for emergency bypass of the fish collected by the channel directly to the tailrace via a spillway bay.

The Type 1 SBC design would vary slightly depending on where this structure was constructed. For illustration purposes, the SBC Type 1 design is shown in Figure 4-1 as it would be applied at Lower Granite Dam. (Refer to Annex B for a more detailed description of how SBC Type 1 designs would be applied to Lower Granite, Little Goose, and Lower Monumental dams).

As with all the designs evaluated in this report, ESBS intake diversion screens would be used in conjunction with the SBC. Screens are already in place at Lower Granite and Little Goose dams.

Design and Operational Information

SBC Channel

The application of the SBC Type 1 design includes a floating collector channel that would span across the entire upstream face of the powerhouse intake structure. A portion of the channel accommodates the secondary dewatering screen section.

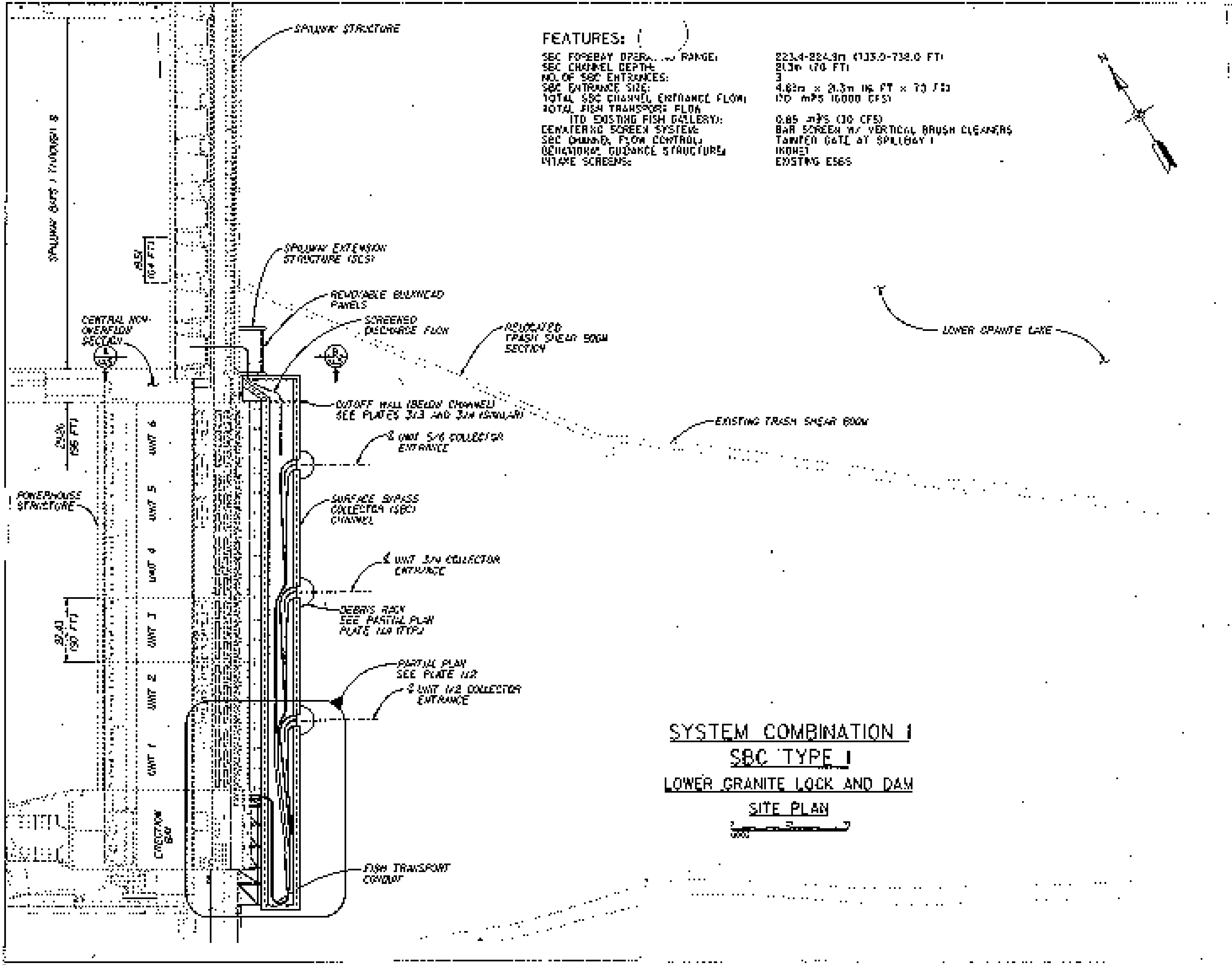

Figure 4-1. SBC Type 1 Design as Applied at Lower Granite Dam (Plan View)

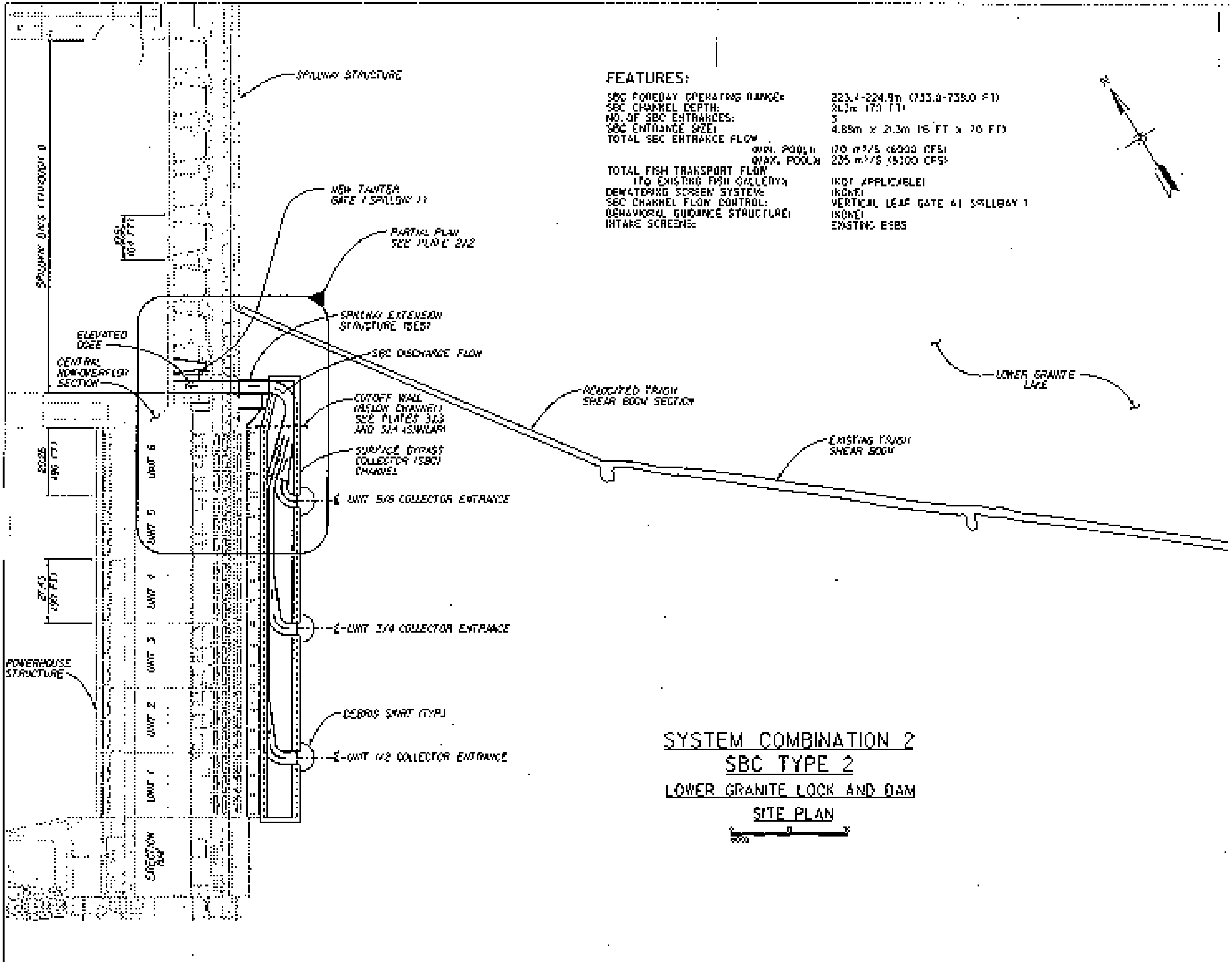

Figure 4-2. SBC Type 2 Design as Applied at Lower Granite Dam (Plan View)

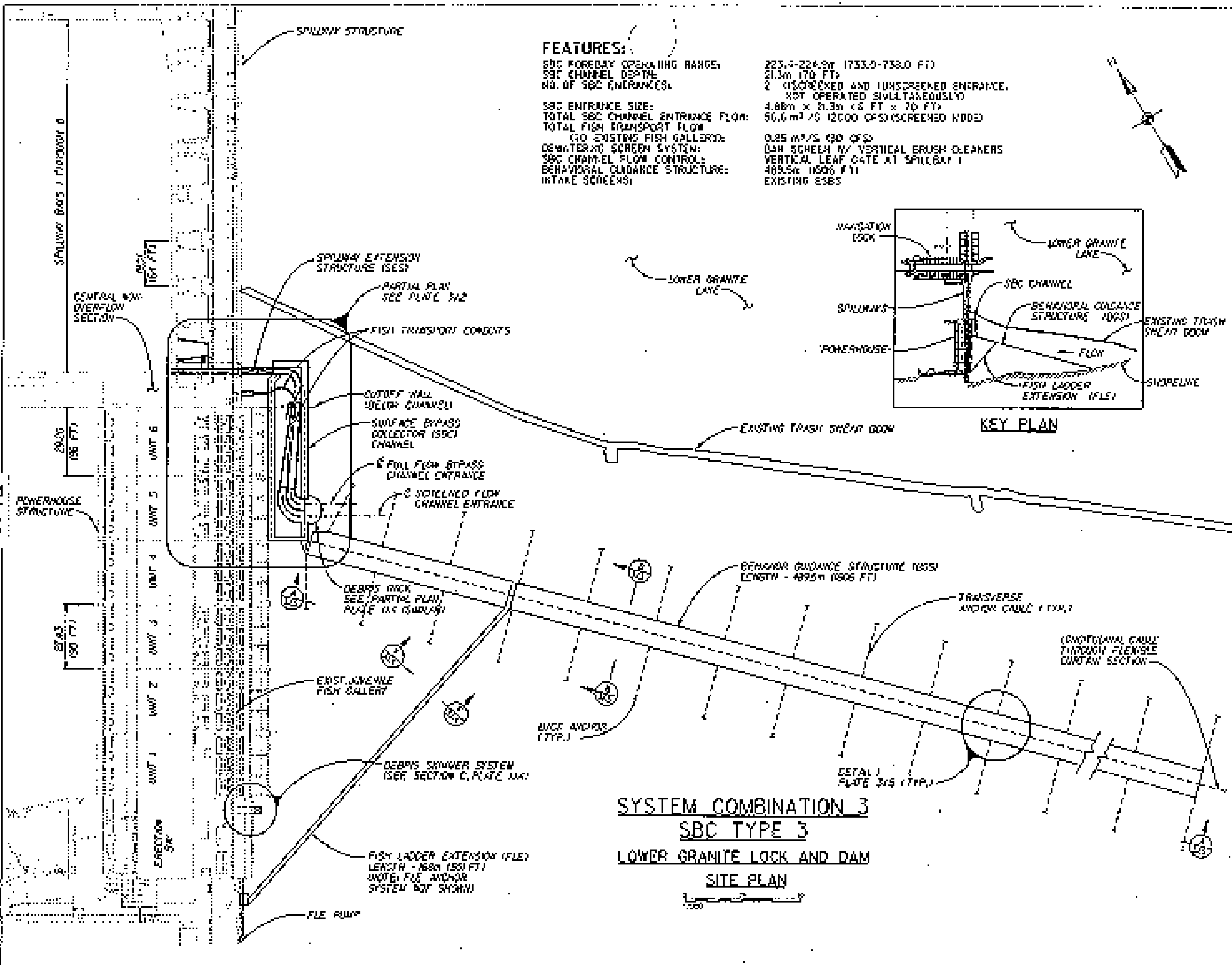

Figure 4-3. SBC Type 3 Design as Applied at Lower Granite Dam (Plan View)

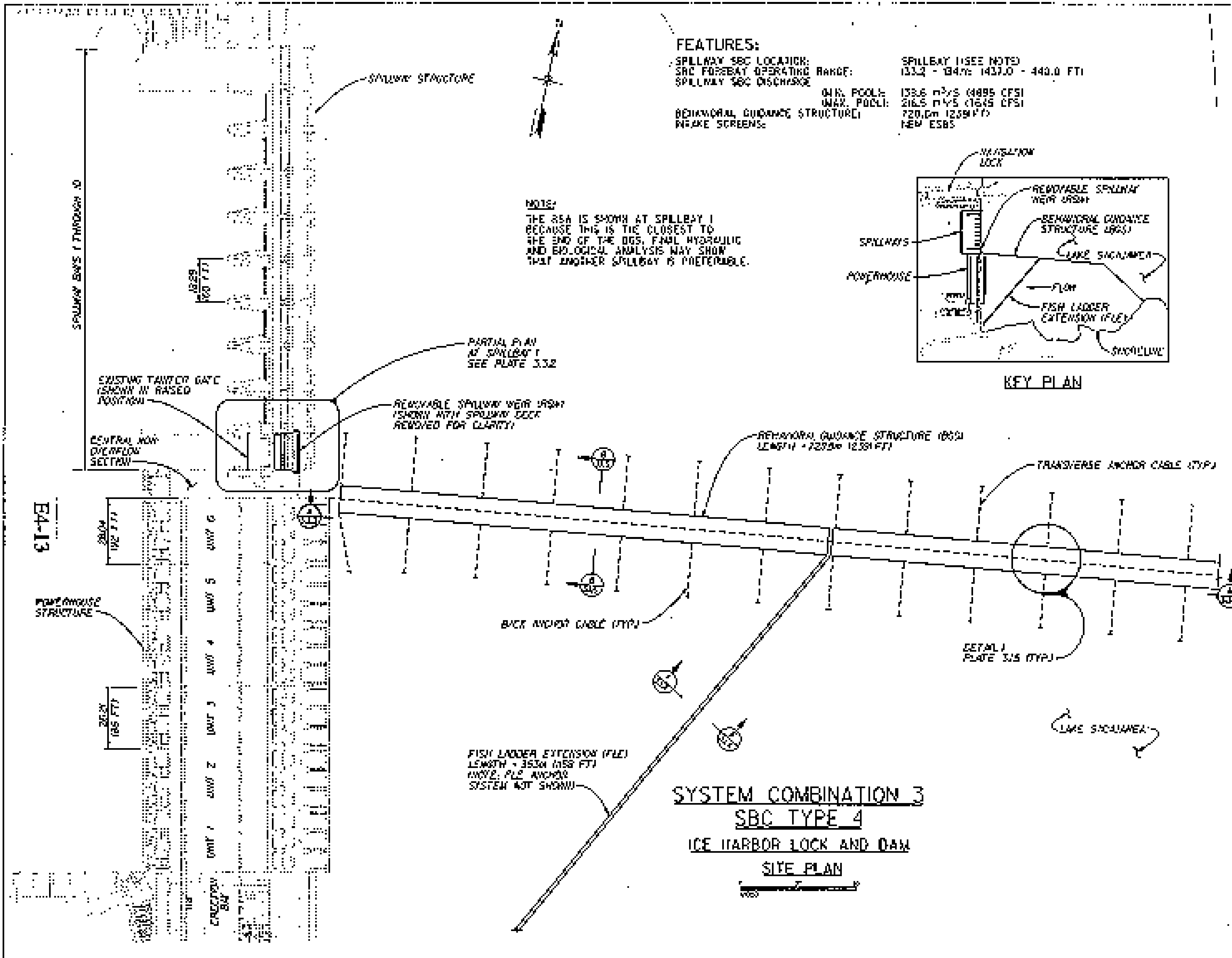

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Figure 4-4. SBC Type 4 Design as Applied at Ice Harbor Dam (Plan View)

During testing of the prototype SBC channel at Lower Granite dam, there were indications that migrating fish in the forebay upstream of the spillway were being attracted under the north end of the channel and into the Unit 6 intake. Therefore, as part of this design, a cutoff wall is included below the channel at the end of the powerhouse closest to the spillway in order to preclude fish movement under this end of the channel directly from the spillway area into the closest unit intake.

SBC Entrances, Flows, and Dewatering

Three vertical entrances into the channel would be located along the upstream wall of the channel. The entrances are located close to every second unit joint. Flow into each entrance is 56.6 m^3/s (2,000 cfs) for a total combined SBC attraction flow of 170 m^3/s (6,000 cfs). Each entrance is outfitted with a full-height semicircular trashrack.

Fish enter the channel through one of the three entrances, each of which are 4.88 meters (16 feet) wide. The floor of the channel coincides with the bottom of the entrances located 21.3-meters (70 feet) below the forebay water surface. Each entrance is associated with a transport conduit that includes a primary dewatering section. The primary dewatering is accomplished independently for the flow entering each of the three entrances. After passing through the primary dewatering screen section, the remaining flow in the three individual conduits is progressively combined into a single conduit leading to a common secondary dewatering screen section. The secondary screening reduces the combined flow, which contains the fish from all three entrances, to a quantity that can be added to the existing juvenile gallery, approximately 0.85 m^3/s (30 cfs).

SBC Entrance Operation

Under normal operation, SBC entrances are all fully open. Bulkhead panels are provided which can be slid down into the flow path both upstream and downstream of each of the three primary dewatering sections to shut off the flow to the primary screens. Emergency bypass doors are located in each conduit upstream of the bulkhead guides to allow for direct bypass of fish and flow to the tailrace when the bulkheads are installed. This approach allows for the flow through a single entrance to be bypassed directly to the tailrace in the event the screening section requires maintenance, without impacting the hydraulics of the flow through the remaining entrances. In addition, this design offers increased operational flexibility in that the flow through an individual conduit can be shut off during periods of low river flow when all units are not operating. In the event that the existing juvenile facilities require maintenance or downtime, the flow through all three entrances can be bypassed directly to the tailrace by placing the upstream bulkheads in all three conduits and opening the emergency bypass doors.

Connection to Existing Juvenile Fish Facilities

After all dewatering is accomplished, the remaining transport flow is delivered with the fish to a location at or near the Erection Bay portion of the powerhouse. The transport conduit in the channel is outfitted with a tilting weir control structure so that the final transport flow can be maintained at 0.85 m^3/s (30 cfs). Flow over the control weir spills into a stationary channel attached to the dam. The channel then passes the flow into the juvenile fish gallery inside the dam.

An opening will be excavated in the concrete wall to accommodate the channel and to allow the 0.85 m^3/s (30 cfs) transport flow to pass as an open channel flow into the gallery. This opening will also house a surface skimming cleaner to remove any floating debris that accumulates. Once in the juvenile fish gallery, the fish are transported downstream in a non-pressurized flume to the fish handling facilities for eventual transport or release to the tailrace, dependent upon the project and selected project operations.

Screened Water Discharge to the Spillway

The screened discharge from the four channel dewatering screen sections (three primary and one secondary) passes from the screens into the main portion of the floating channel, which forms a common discharge channel. This screened flow travels to a spillway extension structure (SES) attached to the upstream face of the nearest spillbay piers. The SES forms a well upstream of this spillbay so that the Tainter gate can be used to regulate and pass the SBC screened flow. The SES is a concrete-filled steel shell forming two walls and a floor bolted to the upstream face of this spillbay. The upstream end of the structure is closed off by means of removable steel stop logs. This design allows for removal of the stop logs so that the full spillway flood discharge capability of this spillbay can be maintained. With the maximum flood of record being less than half the combined discharge capacity of eight spillbays, it is anticipated that this procedure would be required extremely infrequently. However, if this were to be necessary, one additional step would be to install a closure panel over the opening between the channel and the SES to hydraulically separate the two structures. This would be required to prevent the large spill flow passing through the SES from creating a dangerously large head differential between the forebay and the inside of the channel.

Type 2 - Full Length SBC Powerhouse Channel Bypass without Dewatering

Overview

Like the Type 1 SBC design, the goals of the Type 2 SBC channel include providing a surface collector system at the powerhouse designed to attract fish away from the turbine intakes. However, unlike the Type 1 SBC, the operational goal of this channel is to deliver the fish with the full flow directly to the tailrace, with no dewatering of the flow taking place (i.e., no dewatering screens). An additional goal of this design is to provide a discharge for the channel that is a surface withdrawal (rather than a pressurized release) and that also minimizes the impact on the ability of the project to pass flood flows.

The Type 2 SBC design would vary slightly between projects. For illustration purposes, the Type 2 SBC design is shown in Figure 4-2 as it would be applied at Lower Granite Dam. (Refer to Annex B for a more detailed description of how Type 2 SBC designs would be applied to all of the projects).

As with all the designs evaluated in this appendix, ESBS intake diversion screens would be used in conjunction with the SBC. The screens are already in place at Lower Granite and Little Goose dams.

Design and Operational Information

SBC Channel

This full-flow bypass design (Type 2 SBC) includes a floating SBC channel that spans across the entire upstream face of the powerhouse intake structure. The channel is 21.3 meters (70 feet) deep by 14.0 meters (46 feet) wide with three collector entrances along the upstream wall, similar to the Type 1 design. The channel extends from the far end of powerhouse to the middle of the closest spillbay.

The fish enter the channel through the entrances, which are 4.87 meters (16 feet) wide and 21.3 meters (70 feet) high. The exception to this is at Ice Harbor where the entrances are 16.8 meters (55 feet) high. The floor of the channel coincides with the bottom of the entrances. After entering the channel, the fish are diverted 90 degrees towards the spillway. Each entrance is associated with an individual transport conduit. The width of each individual conduit narrows down to 1.83 meters (6 feet) and is maintained at this constant width up to the part of powerhouse closest to the spillway where all three conduits combine together to form a single conduit 6.1 meters (20 feet) wide. The floor of the conduits slopes up through the section where the conduits come together. The combined conduit then gradually converges to a width of 4.88 meters (16 feet) in front of the central non-overflow section of the dam where the conduit makes a 90-degree turn toward the west and joins the fixed SES attached to the upstream face of the closest half of the nearest spillbay. All the flow that enters through the collector entrances travels through the transport conduits, into the SES, and ultimately over the overflow ogee to the tailrace. This is different than a normal spillway (and different than Well's Dam on the mid-Columbia River), since fish are not exposed to the high velocities and abrupt pressures changes that would be associated with an underflow spillway gate.

Like the Type 1 SBC channel, a cutoff wall has been included below the channel at the end closest to the spillway in order to preclude fish movement beneath the end of the channel near the spillway. The wall design would be similar to that described for the Type 1 SBC channel.

SBC Entrances and Flows

The SBC channel has three vertical entrances through the upstream wall. The entrances are located near every second unit joint. Flow through each entrance is approximately 56.6 m^3/s (2,000 cfs), for a combined SBC collection flow of 170 m^3/s (6,000 cfs), when the forebay is at the minimum operating pool. For this design, the entrances do not have full-height debris racks, since most debris entrained in the flow would simply pass though the system to the tailrace. A debris skirt is placed in front of the entrance to minimize floating debris entering the channel. Similar to the Type 1 trashrack, this is a semicircular shape, but rather than being the full entrance height, it extends only about 1.5 meters (5 feet) deep.

SBC Channel to Spillway Connection and Spillway Modification

The floating structure connects to a fixed spillway extension structure (SES) extending from the face of the nearest spillbay. This spillbay is modified to form a 4.88-meter (16-foot) wide overflow ogee for surface withdrawal from the SBC channel. Half of the spillbay is preserved at its full depth and will function in the same manner as the other seven spillbays, except at about half the discharge. Modifications of the spillbay include construction of a new 2.74-meter (9.0-foot) wide pier and trunnion block at approximately the middle of the spillbay to define the extent of the full depth spillbay leaving a 7.6-meter (25-foot) wide full depth spillbay. Half of the spillway will be filled with concrete to define the new higher ogee crest.

A new underflow vertical leaf gate is provided at the elevated ogee for on/off control of the SBC channel discharge. During normal operation of the channel, the leaf gates are hoisted out of the flow path, allowing free overflow at the weir within the normal SBC operating range that corresponds to normal pool fluctuations. At forebay elevations above normal pool, the leaf gates would either close completely or throttle flow. Presumably, forebay elevations higher than normal pool would be outside the operating window of the SBC fish passage requirements, and passage of flow through the SBC during these periods would be strictly for the purpose of adding spill capacity during flood discharge.

To accommodate the narrower spillway at half of the nearest spillbay, the existing Tainter gate would be removed and replaced with a new, narrower tainter gate sized to fit the reduced spillbay width of 7.6 meters (25 feet). At project flood forebay elevations, it is anticipated that the closest spillbay in its modified condition, in combination with the SBC capacity, would be able to pass about 60 percent of its pre-modified capacity. For the entire spillway, the modifications to the closest spillbay would result in a total discharge capacity over 95 percent of the unmodified project capacity. The portion of this total project capacity released through the SBC would be approximately 340 m^3/s (12 kcfs).

Raising the spillway crests would reduce the total capacity of the spillway to pass the standard project flood by about 3.8 percent at Ice Harbor and 5 percent at Lower Granite, Little Goose, and Lower Monumental dams. If no approval to reduce spillway capacities by the amount shown above is provided, alternative methods of bypassing fish or high flows may be implemented. Refer to Section 8.4.3 and Annex B for more detailed discussions of this issue.

Type 3 - Two-Unit SBC Powerhouse Channel and BGS System with Dual Passage Options

Overview

The design goal of the Type 3 SBC channel design is to provide a surface collection channel that combines the operational objectives of both the Type 1 and Type 2 SBC designs. That is, the floating channel allows for either a screened flow operation which passes the fish into the existing juvenile gallery, or a full-flow bypass operation which passes the fish directly to the tailrace. To maximize the effectiveness of either operating scenario, two separate conduits are provided within the channel to accommodate the two modes of operation. Unlike the Type 1 and Type 2 designs, the Type 3 SBC channel extends over only two units at the spillway end of the powerhouse. This design includes a collection channel extending across the front of two powerhouse units located at the end of the powerhouse nearest the spillway. To guide fish away from the other units, a BGS is located in the forebay. The BGS would guide fish to the entrances in the SBC. The channel includes two side-by-side vertical entrances, one for each conduit, although only one would be open at a time.

The Type 3 SBC design would vary slightly depending on where this structure is constructed. For illustration purposes, the SBC Type 3 design is shown in Figure 4-3 as it would be applied at Lower Granite Dam. (Refer to Annex B for a more detailed description of how SBC Type 3 designs would be applied to Lower Granite and Lower Monumental dams). A Type 3 design utilizing a straight line BGS would not be used at Little Goose dam, since a straight BGS would block navigation. Instead, a Vee-shaped BGS would be needed in the forebay requiring two fishway entrances and related features.

As with all the designs evaluated in this report, ESBS intake diversion screens would be used in conjunction with the SBC. The screens are already in place at Lower Granite and Little Goose dams.

SBC Channel, SBC Entrances, Flows, and Dewatering / No Dewatering Components

Many of the SBC channel features for the Type 3 SBC design are similar (with a few subtle differences) to those previously described for the Type 1 or Type 2 designs. These features include a floating channel with internal fish conduits, a cutoff wall below the channel at the end closest to the spillway, dewatering, and connection to the existing juvenile fish facilities for the transport route, as well as a channel attachment to a stationary SES located at the closest spillbay.

Each of the two entrances is 4.88 meters (16 feet) wide by 21.3 meters (70 feet) deep, with the bottom of the channel coinciding with the invert of the entrances. A vertical array of sliding or rolling gate panels would close off either one or the other entrance at any given time. Discharge would be controlled by a modified portion of the spillbay located closest to the SBC. This design would be similar to the design described for the elevated spillway for the Type 2 design previously discussed. However, this new section of spillway would be narrower than that described for Type 2 since the flow rate is lower. This discharge could be open surface discharge, or controlled by lowering the vertical leaf gate into the flow to maintain a constant flow rate for different operating conditions. The system is designed to pass a relatively constant entrance flow of 56.6 m^3/s (2,000 cfs) while in screening mode. When operating in the screening mode with the forebay at or above minimum operating pool, the leaf gate would be used to control the flow so the hydraulic conditions on the screens remain constant. Operating in the bypass mode with no gate control would result in an entrance flow of approximately 67.8 m^3/s (2,392 cfs) at minimum operating pool for both Lower Granite and Lower Monumental dams. Operating in the bypass mode at maximum operating pool, the flows would be approximately and 90.9 m^3/s (3,209 cfs) at Lower Granite dam and 81.1 m3/s (2863 cfs) at Lower Monumental dam.

BGS and Fish Ladder Extension

The downstream end of the BGS is located at the end of the channel, near the unit joint between the two units closest to the spillway. The structure extends from this location upstream about 489.5 meters (1,606 feet) at Lower Granite dam and 556 meters (1,824 feet) at Lower Monumental dam to reach the shore. The upstream end of the BGS is closed off to preclude juveniles from entering the excluded area behind the BGS. A fish ladder extension (FLE) structure has been added to the existing south-bank fish ladder exit to a point approximately one quarter of the distance along the BGS. This ladder extension effectively relocates the ladder exit from the face of the dam to a location on the upstream side of the BGS and gives adult fish a direct path from behind the BGS to points upriver.

Type 4 - Modified SBC Spillway Bypass

Overview

The goal of the Type 4 SBC design is to provide an SBC facility at the spillways to divert fish away from the powerhouse and toward the spillway. One or more spillbays would be modified so each provides an overflow spill of approximately 170 m^3/s (6,000 cfs) at the surface of the forebay in order to attract and safely pass the fish directly to the tailrace. A removable spillway weir (RSW) would be used to serve this function at Ice Harbor.

The Type 4 SBC design has been developed conceptually in this appendix just for Ice Harbor Dam (refer to Annex B). However, it is likely that similar designs could be applied successfully at Lower Monumental and Lower Granite dams. For illustration purposes, the SBC Type 4 design is shown in Figure 4-4 as it would be applied at Ice Harbor Dam. A Type 4 design utilizing a straight line BGS would not be used at Little Goose Dam since a straight BGS would block navigation. Where full bypass to a spillway is the desired goal, a full powerhouse Type 1 SBC design would be more appropriate for Little Goose Dam.

As with all of the designs evaluated in this report, the turbine intakes located behind the BGS will be outfitted with ESBS intake diversion systems which would divert fish passing below the BGS into the existing juvenile gallery and eventually to the juvenile facilities downstream. In the case of Lower Monumental and Ice Harbor dams, the intakes are currently outfitted with an STS diversion screen system that would be removed and replaced with a new ESBS system. ESBS systems are already in place at Lower Granite and Little Goose dams.

Removable Spillway Weir (RSW)

The RSW is a removable steel ogee-shaped structure that is inserted into the existing spillbay, creating a raised overflow weir above and upstream of the existing concrete ogee crest. No modifications, except the addition of support brackets, would be required to the existing spillway to accommodate the RSW. The elevation of the new crest is designed to pass approximately 170 m^3/s (6,000 cfs) in an uncontrolled, open-channel flow condition at the average operating pool elevation. The flow would be either on or off, determined by whether the tainter gate is in a fully open or fully closed position. Since the flow is essentially uncontrolled, the flow rate would vary depending on the forebay water surface elevation. Discharge would be greater when the forebay is at maximum operating pool and smaller when at the minimum operating pool.

A BGS is included in the forebay to guide fish away from the powerhouse and toward the spillway. The basic design and function of the BGS is the same as was described for the Type 3 design. However, for the Type 4 design, the downstream end of the BGS would be located between the powerhouse and the spillway. Since the entire powerhouse flow for all six turbines must pass below the BGS in this case, the BGS must be considerably longer than the Type 3 BGS. The Type 4 BGS would extend 729 meters (2,391 feet) upstream at Ice Harbor.

The RSW is designed to float into place and be submerged into position on the concrete spillway. The hollow steel structure would be filled with air for floating and towed to the spillway with an assist vessel. When the RSW is in the vicinity of the spillbay, portions of the volume would be selectively filled with water to rotate the structure into a vertical position. Once it is vertical, it can be pushed (or pulled with winches on the deck) into its final position above the existing spillway and further submerged until it rests on support brackets permanently mounted to the upstream face of the spillway.

In the extremely rare event that the original spillbay capacity is required to pass a standard project flood, the RSW would be removed and stored. The RSW would be replaced following a reduction in river flow.

The best shape of the downstream portion of the RSW to provide a fish-friendly bypass would have to be determined from prototype testing.

4.4.4 Lower Granite Prototype Tests and Predicted Future SBC Performance

4.4.4.1 Background

Lower Granite Dam was selected for prototype development because it is at the upper end of the system where large numbers of juvenile salmon and steelhead pass, and because of concern for stocks listed as endangered under the ESA. Efforts at other projects have fed into SBC prototype development efforts at Lower Granite.

The first SBC prototype test (a three-unit SBC) at Lower Granite was conducted in 1996. A repeat of the same structure, with varying SBC gate and project operations, was completed in 1997. Test results showed that a surface-oriented juvenile fish system could safely collect fish in significant numbers. However, in order to more closely approach or exceed the high performance observed at Wells Dam, further development and testing was completed. In 1998, an SWI was inserted into the turbine intakes to work in conjunction with the original SBC structure in order to more closely simulate flow conditions that occur at Wells Dam. In addition, a BGS was tested in 1998. The BGS test was to evaluate the concept of a deep physical barrier with relatively low velocities passing beneath the structure, working in combination with a general downstream angled river flow to keep fish away from turbine units behind the BGS.

4.4.4.2 Predicted Fish Performance for Different SBC Types Based on 1998 Lower Granite Prototype Test Results

Preliminary results from 1998 SBC/BGS prototype tests were used to develop estimates of what performance might be expected from a permanent SBC system at a dam. These estimates used hydroacoustic fish passage data gathered during the spring 1998 juvenile salmonid outmigration at Lower Granite Dam. The hydroacoustic data are believed to provide the best indication of the fish run at large, with relatively large sample sizes. Radio telemetry was also used in 1998 to assess the performance of the SBC and BGS. Radiotelemetry provides species-specific information, but uses relatively small sample sizes, so variability is increased. The data from the two studies tend to support each other. However, radiotelemetry estimates of SBC passage for spring chinook and wild steelhead were generally lower than those found from hydroacoustic testing. Conversely, some passage estimates using radiotelemetry for hatchery steelhead were higher than hydroacoustic estimates.

In the following paragraphs, several terms are used to describe the effectiveness of various fish passage measures. Fish guidance efficiency (FGE) refers to the ratio of the fish guided by turbine intake screens as a percentage of all fish passing into the turbine entrance. Combined bypass efficiency (CBE) refers to the total number of fish guided by the screens or collected by a surface collector, as a percentage of the total number of fish approaching the powerhouse. Fish passage efficiency (FPE) refers to the total number of fish passing the dam by any means except through the turbines as a percentage of all fish passing the dam.

SBC passage estimates for the various SBC types were all derived from a value of 62 percent for R(4-5) for the best performing SBC entrance. This means that 62 percent of the fish passing through the SBC, plus Units 4 and 5, plus the screened bypass system actually passed through the SBC. This is a good measure for SBC efficiency since flows to Turbine 6 came largely from the north across the spillway forebay and went under the end of the SBC where there was no SBC entrance and no SWI component. A permanent SBC would likely have a cutoff wall included below the channel, at the end of the powerhouse closest to the spillway. The cutoff wall would preclude fish movement under this portion of the channel directly from the spillway area to the Unit 6 intake.

The FGE value of 82 percent was used for all units with all SBC types. While different FGE values were measured for different units and different groups of units under different configurations of the SBC and BGS, 82 percent represents an overall FGE value for the entire powerhouse.

For a Type 1 or 2 SBC (full powerhouse with or without dewatering), it is estimated that 62 percent of the fish passing the powerhouse would move through the SBC. About 82 percent of the remaining 38 percent, (31 percent of all fish passing the powerhouse) would be guided by the screens (the FGE value used for this analyses is 82 percent), leaving 7 percent of the total number of fish passing the powerhouse that move through the turbines. As a system, this gives a CBE for SBC and screens of

93 percent. The SBC, in this case, provides an 11 percent increase in FPE over the present screen bypass system.

For a Type 3 SBC (partial powerhouse with a BGS), the analysis becomes more complicated. For 100 fish approaching the dam, with 78 percent of those fish approaching Units 1 through 4 would be diverted over to Units 5 and 6. If we assume the initial distribution of fish to be equal at all six units (with no BGS in place), this means that approximately 85 percent of the fish are now in front of Units 5 and 6, where the SBC is located. Sixty-two percent, or 53 fish, enter the SBC, while 32 fish enter the turbine intakes, where 26 of them are guided by the screens, and 6 pass through the turbines. The remaining fish at Units 1 through 4 would total 15. Twelve of these are guided, and three pass through the turbines. As a system, this means that 53 percent pass through the SBC, 38 percent are guided by the screens, and 9 percent pass through turbines. CBE is 91 percent, with the SBC providing a 9 percent increase over screens alone in FPE.

A Type 4 SBC would consist of a BGS leading to a modified spillway entrance. There is no SBC associated with the powerhouse. For purposes of this discussion, it is assumed that a BGS to the spillway will divert fish at a similar rate as the prototype BGS that covered only the south half of the powerhouse. While this may not be the actual diversion probability of a structure in this location, it reflects what was measured on the prototype in 1998. This being the case, 78 percent of the fish approaching the powerhouse would be diverted to the spillway. The remaining 22 percent would enter the turbine intakes, with 18 percent being diverted by the screens, and 4 percent passing through the turbines. This gives an FPE (or CBE) of 96 percent. The BGS with spillway passage provides a 14 percent increase in CBE over screens alone. This system has no provisions for transport of fish.

Predicted SBC performance data for the different SBC design types are summarized in Table 4-2, below. Also shown are predicted project survival numbers associated with each of the different SBC types.

Table 4-2. SBC Performance Data Presented as a Percentage of All Fish Approaching the Powerhouse (Not Spilled)

SBC Type	FGE and CBE			Fish Passage Route			
	FGE Alone %	CBE %	Increase %	Screened Bypass %	SBC %	Turbine %	Project Survival* %
Type 1, 2	82	93	11	31	62	7	98.8
Type 3	82	91	9	38	53	9	98.6
Type 4	82	96	14	18	78	4	99.1

(* Survival Number Assumptions: SBC=99.5%, Screened Bypass=99.5%, Turbine=89%)

4.4.5 Rationale Used for Development of SBC Types Used for Different SBC System Combinations

4.4.5.1 General

An SBC Conceptual Design Report completed in 1998 included ten SBC options for Lower Granite Dam. The options were compared to one another to determine the best transportation, bypass, and adaptive migration strategy options for future consideration at the lower Snake River facilities. The goal was to develop several rational SBC systems to be investigated further. Several meetings were held by Corps biologists and engineers to discuss which SBC options should be used for development of the SBC system combinations. The Corps coordinated with regional specialists to achieve a consensus on the SBC system combinations to be studied.

The SBC combinations selected are described in detail in the Surface Bypass and Collection System Combinations Conceptual Design Report (SBC Combinations Concept Report). The report was completed in December 1998 and is included in full in Annex B. The Major System Improvement Options included in this appendix are based upon this report. The following paragraphs reference the SBC Combinations Concept Report.

Because there is currently no widespread regional agreement on whether transporting the juvenile fish is better or worse than keeping the fish in-river, it was decided to develop several system combinations. Two SBC system combinations will be investigated in this appendix which keep fish in-river for downstream migration. Also, there are two SBC combinations investigated that utilize a fish transportation system with one combination at a significantly reduced cost. Finally, there is another system combination studied in this appendix that allows for both transportation and in-river bypass.

4.4.5.2 SBC Structure with SWI Component

The preliminary data from the SBC prototype testing indicated that the SWI and ESBS worked well together to achieve a high collection rate. Because of this, 21.3 meter (70 foot) deep surface collectors were selected over 16.7 meter (55 foot) deep surface collectors for further consideration at Lower Granite, Little Goose and Lower Monumental dams. At Ice Harbor Dam, the forebay depth is considerably shallower and the powerhouse structure is configured such that a 16.7-meter (55-foot) deep surface collector would appear more appropriate for working together with the ESBS. Use of ESBS intake diversion screen systems is assumed for each SBC type, at each project, for each system combination.

4.4.5.3 SBC Structure with BGS Component

The performance data for the BGS were inconclusive at the time of development of the SBC combinations. Also, as described in Annex B, the cost for a deep full powerhouse surface collector with dewatering is only about 15 percent higher than for a deep partial powerhouse surface collector with dewatering and a BGS. Also, it was felt that if a full powerhouse surface collector were feasible then a partial powerhouse surface collector with a BGS would also be feasible. The reason for this is that the most challenging aspect of development of a full powerhouse SBC is the large scale dewatering, assumed to be about 170 m^3/s (6,000 cfs). A partial powerhouse surface collector would have much less dewatering, approximately 56.6 m^3/s (2,000 cfs). Also, development of a BGS was found to be feasible in the SBC Combinations Conceptual Report. For the reasons stated above, it was felt that a reasonable choice for the bypass and transport SBC system combinations would include full powerhouse surface collectors. If it is later found conclusively that the BGS testing is indeed successful, then it is likely that less expensive partial powerhouse surface collectors with BGSs could be developed in lieu of full powerhouse surface collectors to collect fish for transportation. Also, the BGSs could be used in lieu of full powerhouse surface collectors to guide fish directly to a spillbay for bypass. However, concern was raised regarding the complete exclusion of BGSs from the SBC Combinations Concept Report. It was agreed that it was inappropriate to exclude consideration of this emerging technology prior to the completion of prototype testing. Consequently, it was decided to include BGSs in the Adaptive Migration

Strategy System Combination described in the SBC Combinations Concept Design Report. That way, BGS technical and cost issues would be included in the report.

The most recent results from the prototype testing indicate the BGS is effective at guiding fish. Because of this, a Major Systems Improvement Option, not contained in the SBC Combinations Concept Design Report, is included in this appendix (Option A-6d). This additional option includes use of BGSs to guide fish to the spillway.

4.4.5.4 Dewatering

The SBC Combinations Conceptual Design Report for Lower Granite included a dewatering system for a full powerhouse surface collector utilizing conventional dewatering criteria. Conventional criteria includes a 0.12 m/s (0.4 fps) screen approach velocity component, as defined by NMFS, for screen applications where salmonid fry may be present. Also, the conceptual design report included several full and partial powerhouse surface collector options utilizing more progressive dewatering criteria. The criteria includes a higher screen approach velocity, varying gradually between 0.36 m/s (1.2 fps) in the upstream portion of the dewatering channel to the NMFS mandated 0.12 m/s (0.4 fps) in the downstream portion of the channel. Preliminary dewatering model testing utilizing the progressive criteria has been completed and has provided promising results. However, more model testing and, eventually, full-size prototype testing would be required to determine the full effects of various dewatering scenarios on fish. Use of the conventional dewatering criteria would result in a much larger and more expensive surface collector. Also, the fish entrances would be further upstream, and the fish would experience a longer travel time through the surface collector. For all these reasons, it was decided that the surface collectors developed for the SBC Combinations Concept Report would utilize "progressive" dewatering criteria.

Although not evaluated as part of this report, energy conservation measures related to excess flows removed during dewatering will be evaluated in future studies. This may mean that excess SBC discharge may be routed to a turbine to capture the energy that would be lost, or water may be added to adult collection systems in order to take the place of flow currently provided by pumps or fishwater turbines.

4.4.5.5 Spillway Fish Bypass Structure

Regional experts, including Corps biologists and engineers, compared methods of bypassing fish over the spillway. One method included in the SBC Combinations Concept Report utilized a chute structure to guide fish over the spillway. With the chute design, the fish would experience a high-velocity free plunge from the end of the chute into the spillway tailwater. This would be a near-vertical, drop-off at the end of the chute, as opposed to a spillway-type flow that is supported by the spillway concrete and guided into the tailwater. This free plunge was seen as possibly being detrimental to the fish. Another method developed in the report included raising the spillway crest. This method was seen as likely causing less fish stress, since it would discharge the fish into the tailwater in the same way the existing spillway does and would include no free plunging water. Consequently, the in-river bypass and adaptive migration strategy SBC system combinations contained in the SBC Combinations Concept Report include raised or modified spillbays.

4.5 Miscellaneous Measures

4.5.1 General

Miscellaneous measures to upgrade present facilities to state-of-the art designs and operations are assumed to consist of items listed in the following paragraphs. A description of how these improvements may be grouped together to improve the existing system's effectiveness for bypassing and/or transporting fish is included in Section 5 of this appendix.

4.5.2 Adult Fish Attraction Modifications

The adult fish attraction water at selected projects would be modified in order to insure an adequate water supply for the fish ladders in the event of a pump failure. This may include electrical upgrades to provide a more reliable source of electrical power to the attraction water pumps, upgrading existing pumps, adding new pumps, or adding a gravity feed system for the attraction flow.

4.5.3 Upgrade to Lower Granite Juvenile Fish Facilities

Lower Granite Dam is the first dam downstream that migrating juvenile fish pass on the lower Snake River. Under a fish transportation operating scenario, without in-river bypass, the highest percentage of fish transported downstream from the lower Snake River would be transported from Lower Granite Dam. Under an in-river, bypass-only operating scenario, all downstream migrating fish would pass Lower Granite Dam. Therefore, it is important to incorporate improvements to minimize fish stress and to optimize the effectiveness of the juvenile fish facility at Lower Granite Dam. Listed below are potential improvements to the Lower Granite facility. The selection of specific items for implementation depends upon whether the facility would be used for fish transport, bypass, or both. The proposed modifications are derived from improvements in fish facility technology gained in recent years. Upgrading the juvenile fish facilities at Lower Granite would include the following:

- Replacing the 36 254-mm (10-inch) orifices extending from the bulkhead slots to the juvenile fish collection gallery with 36 305-mm (12-inch) orifices. Each orifice would be equipped with an air operated knife valve, and an air back-flush system for dislodging debris. The valves would be automated and controlled with a programmable logic control computer so they could be cycled to prevent clogging.
- Mining the gallery to a 2.7-meter (9-foot) width so orifice flow would not strike the far wall. The gallery is currently 1.8 meters (6 feet) wide.
- Mining an exit channel from the dam out to daylight, and installing a non-pressurized flume system to the fish collection facility.
- Installing a dewatering system to reduce the flow from 7.08 m^3/sec (250 cfs) to 0.85 m^3/sec (30 cfs), similar to the design at Little Goose Dam, and routing the excess water to the adult fish collection facility.
- Installing a size separator to separate smaller (primarily salmon) from larger (primarily steelhead) smolts so smaller and larger smolts can be transported in separate truck or barge compartments.
- Upgrading raceways and distribution flume systems at the collection facility.
- Upgrading direct barge loading facilities.

4.5.4 Additional Fish Barges

Additional barges would be constructed to allow direct loading (thus reducing fish stress) at collector dams. Five additional 22,700-kg (50,000-pound) barges would be required to allow direct loading at lower Snake River collector dams and to replace two existing barges. The two barges being replaced are old hulls (over 50 years old) approaching the end of their serviceable life.

4.5.5 Modified Fish Separators

If prototype testing proves successful, fish separators would be modified to improve fish separation and to reduce fish stress, delay, and mortality at existing juvenile fish facilities. The new separators would be installed at Little Goose and Lower Monumental dams and would be included in an upgrade of the Lower Granite Juvenile Fish Facility.

4.5.6 Cylindrical Dewatering Screens

If prototype testing proves successful, cylindrical dewatering screens may be added to existing juvenile fish facilities in order to improve dependability, and debris handling capabilities, as well as to reduce fish stress. A cylindrical dewatering screen design is under consideration that may be an improvement over existing stationary screen designs. If testing shows the cylindrical dewatering screens are beneficial, they would likely be installed at Little Goose, Lower Monumental, Ice Harbor dams, and included in an upgrade of the Lower Granite Juvenile Fish Facility.

4.5.7 Trash Shear Boom at Little Goose Dam

A new trash shear boom would be constructed in the forebay of Little Goose Dam to capture more of the debris before it can get to the juvenile fish facilities. This debris creates maintenance problems, such as plugging of orifices, which can lead to additional stress on the fish.

4.5.8 Modified Extended Submersible bar screens at Turbine Intakes

Submersible bar screens at Lower Granite and Little Goose dams would be modified to improve their operability and longevity. Modifications might include reducing vibration that causes steel fatigue and cracking and better sealing underwater mechanical equipment to prevent water intrusion. Currently, facilities do not exist at the dams to perform large-scale maintenance. The ESBSs would have to be moved off site to perform this work.

4.5.9 Additional Flow Augmentation

Currently, additional flow from upstream storage in Idaho is used to increase the total river flow in order to speed downstream migration of juvenile fish. This is a requirement of the 1995 Biological Opinion. Many of the options for operating the river described later in this appendix assume the continued use of flow augmentation or an increased amount of flow augmentation.

4.5.10 Anadromous Fish Evaluation Program (AFEP)

There will be continued monitoring and biological evaluations of anadromous fish due to any significant changes made in the dam facilities and operations. The biological evaluations are conducted in three phases: 1) identification of the problem, 2) evaluation of proposed modifications to the facilities or operations to address the problem, and 3) evaluation of post-construction/operation performance.

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5. Existing System Upgrades

5.1 Introduction

Juvenile fish presently pass the dams through turbines, fish bypass systems, or over spillways. In accordance with the 1995 Biological Opinion NMFS issued for operation of the Federal Columbia River Power Systems, the Corps also implements flow augmentation and increased spill measures to help migration. Intake screens are used to guide most of the fish away from turbines and into bypass systems. Juvenile fish are then routed back to the river or into barges or trucks for transport downriver. The 1995 Biological Opinion currently states that about 50 percent of the juveniles are to be transported.

Existing Systems (see Section 3) consist of continuing present fish passage facilities and operations that were in place or under development at the time the feasibility study was initiated. This includes non-fish-related items as well, when considering operation and maintenance costs. Items to be added to present systems (i.e., Existing System Upgrades) are considered important measures to upgrade existing facilities to state-of-the art designs and operations. Depending upon the alternative being evaluated, ongoing improvements would include such things as modified turbine intake screens, additional fish transport barges, additional end bay flow deflectors on spillways, turbine modifications, and others.

Proposed upgrades to the existing system vary somewhat depending upon the assumed method of aiding fish migration, i.e., whether the fish are transported or bypassed. Various upgrades are grouped together as options to improve the effectiveness of these operational scenarios. These options and the corresponding upgrades are described below.

5.2 Option A-1a: In-River Passage with Voluntary Spill

5.2.1 General

Option A-1a assumes that the juvenile fishway systems will be operated to maximize in-river fish passage and that voluntary spill will be used to bypass fish through the spillways.

Measures for Option A-1a that would likely be used to upgrade existing systems are identified in the following sections.

5.2.2 Dissolved Gas Abatement Measures

Since the fish would remain in the river, and voluntary spill would be used to attract the fish to the spillway, it is important to implement dissolved gas abatement improvements. Dissolved gas abatement measures are listed below.

- Spillway gas monitoring for all projects would be continued.
- Two end-bay deflectors would be added at Lower Monumental and Little Goose dams. The added deflectors would include smooth radius transitions and pier nose extensions. See paragraph 4.2.2 for further information related to additional end-bay deflectors.
- The existing deflectors at Lower Monumental, Little Goose, and Lower Granite dams would be modified. See paragraph 4.2.3 for further information related to modified deflectors.

5.2.3 Turbine Measures

Because of the tremendous costs of implementing major changes to the turbines, it is assumed that improvements to the turbines to improve fish passage will be incorporated in the scheduled turbine rehabilitation for each project. The exact nature of this modification has not yet been determined. For the purpose of this study, a minimum gap runner design will be installed in each turbine. This will approximate the cost of incorporating fish passage measures with existing turbines.

5.2.4 Miscellaneous Measures

Unless specifically identified, the existing features, improvements to existing features, and new features that are listed below would apply to all four lower Snake River projects. (See paragraph 4.5 for additional discussion related to these items). The items include the following:

- Existing adult fish passage systems with upgraded adult fish passage modifications
- Existing juvenile fish bypass and collection systems with upgrades to the Lower Granite Juvenile Fish Facilities (less separator, raceway, distribution flume, and direct barge loading upgrades at Lower Granite Dam)
- Minimum operating pools with 527 million cubic meters (427,000 acre-feet) flow augmentation from upstream storage in Idaho. Refer to Section 7 in Annex A for more information
- New cylindrical dewatering screens
- A new trash shear boom at Little Goose Dam
- Modification of the existing extended submersible bar screens at Little Goose and Lower Granite dams
- Continued operation of the fish hatcheries
- Continuation of AFEP evaluations.

5.3 Option A-2a: Maximizing Transport

5.3.1 General

Option A-2a assumes that the juvenile fishway systems will be operated to maximize fish transportation. Under this option, fish would be bypassed only at Ice Harbor Dam. Therefore, voluntary spill is included only for Ice Harbor Dam.

Measures for Option A-2a that would likely be used to upgrade existing systems are identified in the following sections.

5.3.2 Dissolved Gas Abatement Measures

Since most fish would be transported, and voluntary spill is used only at Ice Harbor Dam, it was decided that modifying the existing deflectors was not necessary. However, additional end-bay deflectors at Lower Monumental and Little Goose dams, as described for Option A-1a, were included in this option. Also, spillway gas monitoring would be continued.

5.3.3 Turbine Measures

For this alternative, improvement to the turbine designs that will improve fish passage will likely be incorporated during the scheduled turbine rehabilitation for the particular project. This is the same assumption as is included for Option A-1a.

5.3.4 Miscellaneous Measures

Unless specifically identified, the existing features, improvements to existing features, and new features that are listed below would apply to all four lower Snake River projects. This is the same list of improvements as is included for Option A-1a, except for the following: 1) new barges, 2) new separators at Lower Granite, Little Goose and Lower Monumental dams, and 3) the existing juvenile facility at Lower Granite Dam would have more extensive modifications to improve juvenile fish transportation operations. See paragraph 4.5 for additional discussion related to these items. The list of items for this option include the following:

- Existing adult fish passage systems with upgraded adult fish passage modifications
- Existing juvenile fish bypass and collection systems with upgrades to the Lower Granite Juvenile Fish Facilities
- Minimum operating pools with 527 million cubic meters (427,000 acre-feet) flow augmentation from upstream storage in Idaho
- Additional fish barges
- Modified fish separators at Little Goose, Lower Monumental, and Lower Granite dams
- New cylindrical dewatering screens
- New trash shear boom at Little Goose Dam
- Modification of the existing extended submersible bar screens at turbine intakes at Little Goose and Lower Granite dams
- Continued operation of the fish hatcheries
- Continuation of AFEP evaluations.

5.4 Option A-1: Adaptive Migration Strategy with Voluntary Spill

5.4.1 General

Option A-1 assumes that the juvenile fishway systems will be operated in a manner that will balance the passage of fish between in-river and transport methods. This is the current operational strategy for the lower Snake River dams per the 1995 Biological Opinion. Voluntary spill will still be used to bypass more fish through the spillways.

Bypassing and transporting fish is the current operating strategy for the lower Snake River dams.

Measures for Option A-1 that would likely be used to upgrade existing systems are identified in the following sections.

5.4.2 Dissolved Gas Abatement Measures

This option includes bypassing some of the fish over the spillway and utilizing voluntary spill, approaching the gas cap, to attract the fish to the spillway. These measures are similar to that included for Option A-1a. Therefore, dissolved gas abatement measures proposed for Option A-1 are the same as those included with Option A-1a. These measures include the following: 1) continuation of spillway gas monitoring, 2) additional end bay deflectors and pier extensions at Lower Monumental and Little Goose dams, and 3) modification of existing deflectors at Lower Monumental, Little Goose, and Lower Granite dams.

5.4.3 Turbine Measures

As is included for Options A-1a and A-2a, improvements to turbines to aid fish passage are assumed to occur during a future major rehabilitation of the turbines.

5.4.4 Miscellaneous Measures

The improvements listed in Section 5.3.4 are the same as the miscellaneous improvements that would be appropriate for Option A-1. These measures would improve both the existing transportation and bypass systems. Refer to Section 5.3.4 for a list of these measures.

6. Major System Improvements

6.1 Introduction

Major System Improvements consist of measures beyond previously mentioned Existing System Upgrades that have a high potential of significantly increasing the effectiveness and efficiency of juvenile fish passage around the dams. Based upon current information, the only future development that is included in this category for this report is SBC-related alternatives. SBC alternatives would provide a new method of collecting and/or bypassing fish.

Each Major System Improvements option would include various Existing System Upgrade options, as described in Section 4 of this appendix. The major system improvements would act in concert with upgraded existing systems to provide a significantly improved overall strategy for aiding downstream fish passage. Refer to Section 4.4.3 and Annex B for a more detailed description of the SBC types referenced herein.

6.2 Option A-6a: Major System Improvements—In-River Passage

6.2.1 General

Option A-6a assumes that the juvenile fishway systems will be operated to maximize in-river fish passage utilizing upgrades to the existing system and major system improvements.

Also, 1,760 million cubic meters (1,427,000 acre-feet) of flow augmentation from upstream storage is included in Option A-6a, compared to 527 million cubic meters (427,000 acre-feet) of flow augmentation included with Option A-1a.

Voluntary spill would be used at each dam to attract fish away from the powerhouse, towards the spillway.

Measures for Option A-6a that would be used to improve fish passage conditions significantly, focusing on actions that will particularly facilitate in-river fish passage operations, are identified in the following sections. Refer to Annex B for a more detailed discussion of SBC options related to the in-river passage strategy.

6.2.2 Existing System Upgrades

All Existing System Upgrade measures identified with Option A-1a, as described in Section 5.2, are included with Major Systems Improvements Option A-6a, except for flow augmentation, as described in Section 6.2.1, above.

6.2.3 SBC

The migration strategy for Option A-6a is to focus on effective diversion of the fish away from the turbines for in-river migration. For this combination, all four projects would be outfitted with a Type 2 SBC design. See Section 4.4.3 and Annex B for more detailed information. This means each dam would have a full-length powerhouse SBC channel without dewatering screens. Fish would be passed directly downstream to the tailrace through modified spill flow. To maximize effective diversion away from the turbines, ESBS intake diversion systems would be used in conjunction with the SBC channels at all four dams to divert fish which might pass under the channels and into the turbine intakes. Fish diverted by the ESBS systems would continue to be directed to the juvenile fish facilities where these fish could be delivered directly into the tailrace at that location.

As previously described, Lower Granite and Little Goose dams already have ESBS systems, and these would continue to be used in conjunction with the new SBC channels. The STS systems at Lower Monumental and Ice Harbor dams would be removed and replaced with new ESBS systems.

Table 6-1 below summarizes the SBC types at each project that would make up the SBC system combination for Option A-6a.

Table 6-1. Summary of SBC Types for Option A-6a

System Combination No.	Lower Granite	Little Goose	Lower Monumental	Ice Harbor
Options A-6a: In-River with Voluntary Spill	**Type 2** (Six-Unit Bypass Channel)	**Type 2** (Six-Unit Bypass Channel)	**Type 2** (Six-Unit Bypass Channel)	**Type 2** (Six-Unit Bypass Channel)

6.3 Option A-6b

Option A-6b is identical to Option A-6a, except no flow augmentation is assumed.

6.4 Option A-6d: Alternate In-River Major System Improvement Option

6.4.1 General

Option A-6d assumes that the juvenile fishway systems will be operated to maximize in-river fish passage. This is the same fish passage strategy for Option A-6a except that it uses different SBC components to accomplish the objective. Option A-6d includes the use of a behavioral guidance structure and removable spillway weir (Type 4 SBC) in lieu of a surface collector at each dam, except Little Goose Dam. A full-powerhouse, bypass-only surface collector (Type 2 SBC) system is included for Little Goose Dam.

This option was added late in the study since performance of the BGS was not known at the time a preferred in-river passage alternative was selected to be studied and included in the SBC Combinations Report (reference Annex B). At that time, it was decided to select Option A-6a to be included in the report. However, the most recent data from the prototype testing of the BGS and surface collector at Lower Granite Dam indicate that more fish would be guided to a spillway by a BGS than would be collected with a surface collector. Option A-6d was selected for study during the latter stages of development of this appendix when these data become available. Therefore, inadequate time existed to develop drawings and text in the detail included in Annex B. However, Option A-6d is described in sufficient detail herein by including appropriate references to Annex B.

Option A-6d includes 527 million cubic meters (427,000 acre-feet) of flow augmentation from upstream storage.

Measures for Option A-6d that would be used to significantly improve fish passage conditions, focusing on actions that will particularly facilitate in-river fish passage operations, are identified in the following sections. Since this alternative was added late in the study, this SBC system combination is not evaluated in Annex B. However, a detailed discussion of SBC Types 2 and 4 are included in Annex B. This information was used as a basis for determining estimated costs and an implementation schedule for this option.

6.4.2 Existing System Upgrades

Most of the Existing System Upgrade features identified with Option A-1a in Section 4.2 would be included with Option A-6d. Modification of the existing deflectors at Little Goose Dam is included in Option A-6d because it is assumed Little Goose will have voluntary spill. None of the other projects is assumed to have voluntary spill. Therefore, no modifications to the deflectors are included for the other dams in this option.

6.4.3 SBC

The migration strategy for Option A-6d is to focus on effective diversion of the fish away from the turbines for in-river migration. For this combination, Lower Granite, Lower Monumental, and Ice Harbor dams would have Type 4 SBC systems. At these dams, a BGS would extend upstream from the interface of the powerhouse and spillway. A removable raised spillway weir would be placed on the spillbay adjacent to the powerhouse to provide a more fish-friendly bypass over the spillway. Type 4 SBC systems are described in more detail in Section 4.4.3. There would be no need for voluntary spill at these dams since the BGS is expected to divert about 78 percent of the fish away from the powerhouse, towards the spillway. Refer to Section 4.4.4 for more information on BGS performance.

At Little Goose Dam, an SBC Type 4 would not be used because a BGS would block navigation. Instead, an SBC Type 2 would be employed. See Table 6-2 for a summary of SBC types. Therefore, Little Goose Dam would have a full-length powerhouse SBC channel that would not include dewatering screens. Fish would be collected in the SBC, guided to the spillbay adjacent to the powerhouse, and passed over a raised spillbay, downstream to the tailrace. Voluntary spill would be used to increase the percentage of fish passed over the spillway. Refer to Section 4.4.4 for the effectiveness of SBC.

The existing ESBS intake system at Lower Granite and Little Goose dams would be used to divert fish that pass under the channel and into turbine intakes. Fish diverted by the ESBS systems would continue to be directed to the juvenile fish facilities, where they would be delivered into the tailrace at that location.

A new ESBS system would be installed in the turbine intakes at Ice Harbor and Lower Monumental dams to divert fish from the turbines.

Table 6-2. Summary of SBC Types for Option A-6d

System Combination No.	Lower Granite	Little Goose	Lower Monumental	Ice Harbor
Options A-6d: In-River Passage With BGS Structures (No Voluntary Spill Except at Little Goose)	**Type 4** (Removable Spillbay Weir with BGS)	**Type 2** (Six-Unit Bypass Channel)	**Type 4** (Removable Spillbay Weir with BGS)	**Type 4** (Removable Spillbay Weir with BGS)

6.5 Option A-2b: Major System Improvements with Maximized (High Cost) Transport System

6.5.1 General

Option A-2b assumes that the juvenile fishway systems will be operated to maximize fish transport and that voluntary spill will not be needed.

Option A-2b includes 527 million cubic meters (427,000 acre-feet) of flow augmentation from upstream storage.

Measures for Option A-2b that would be used to upgrade existing systems and significantly improve the effectiveness of fish collection and transportation are identified in the following sections. Refer to Annex B for a more detailed discussion of SBC options used for improving fish transportation.

6.5.2 Existing System Upgrades

Existing System Upgrade features identified with Option A-2a in Section 5.3 would be included with this Major Systems Improvements Option A-2b.

6.5.3 SBC

The migration strategy for Option A-2b is to maximize the number of fish collected and delivered to the transportation facilities located at Lower Granite, Little Goose, and Lower Monumental dams. Ice Harbor Dam is not included since fish can only be bypassed. Fish collection would be accomplished by constructing a full-length powerhouse SBC channel at each of the three upstream projects (Type 1 SBC). The channels would contain dewatering screens to concentrate the fish in a small enough flow that they could be delivered into the existing juvenile bypass channels inside each dam. Emergency bypass openings would also be provided to allow the collected fish to bypass the dewatering screens and pass downstream directly through the spillway if there is a problem with either the dewatering screens or the transportation facilities. The SBC channels would be used in conjunction with ESBS located in the turbine intakes. Fish diverted by the ESBS would also be delivered into the existing juvenile bypass channels. All fish collected would be delivered to the transportation facilities and either trucked or barged downstream. The number of fish continuing downstream by in-river passage through the projects (either through the turbines or spillways) would be minimized and would drop significantly at each consecutive project.

Lower Granite and Little Goose dams currently have ESBS installed in the turbine intakes. These would continue to be used. However, the intakes at Lower Monumental are currently outfitted with submerged traveling screens (STS). These would be removed and replaced with ESBS to increase the screen diversion efficiency and to further reduce the number of fish passing through the turbines.

At Ice Harbor Dam, the turbine intakes are also currently outfitted with STS. As at Lower Monumental Dam, these would be removed and replaced with ESBS to increase the diversion efficiency of the screening system. However, no SBC channel would be installed at Ice Harbor Dam. If the combination of the SBC channels and the ESBS diversion systems function as anticipated at the upper three projects, there should be so few freely migrating fish left in the river reaching Ice Harbor Dam, that construction of an SBC system would not be necessary. This approach is further justified by the fact that no fish enter the Snake River between Lower Monumental and Ice Harbor.

Table 6-3 summarizes the SBC types at each project that make up the system combination for Option A-2A).

Table 6-3. Summary of SBC Types for Option A-2b

System Combination No.	Lower Granite	Little Goose	Lower Monumental	Ice Harbor
Option A-2b:	Type 1	Type 1	Type 1	None
Transport (High Cost) with no Voluntary Spill	(Six-Unit Screened Channel)	(Six-Unit Screened Channel)	(Six-Unit Screened Channel)	

6.6 Option A-2c: Major System Improvements with Low Cost Transport System

6.6.1 General

Option A-2c assumes that the juvenile fishway systems will be operated to maximize fish transport and that voluntary spill will be needed only at Ice Harbor Dam to aid in bypassing fish over the spillways.

Option A-2c includes 527 million cubic meters (427,000 acre-feet) of flow augmentation from upstream storage.

Measures for Option A-2c that would be used to upgrade existing systems and significantly improve the effectiveness of fish collection and transportation are identified in the following sections. Refer to Annex B for a more detailed discussion of SBC options used for improving fish transportation.

The juvenile fish passage strategies for Options A-2b and A-2c are the same. However, there are significant differences in designs and project operations between these two options.

6.6.2 Existing System Upgrades

Existing System Upgrade features identified with Option A-2a in Section 5.3 would be included with this major systems improvements option.

6.6.3 SBC

Option A-2c is a reduced-scale version of Option A-2b, requiring significantly reduced initial and operating costs.

A key justification for implementing Option A-2c is that the majority of juvenile salmon coming down the Snake River starts upstream of Lower Granite Dam. If the combined SBC and ESBS systems to be utilized at Lower Granite function as effectively as anticipated, there would be few migrating fish left in the river below the dam. Considering the potential effectiveness of upgrading the intake screen systems, construction of large, expensive SBC systems may not be justified downstream of Lower Granite Dam.

The migration strategy for Option A-2c, like Option A-2b, is to maximize the number of fish collected and delivered to the existing or upgraded transportation facilities. However, this option relies more heavily on the intake diversions screen systems, since an SBC system would only be used at Lower Granite Dam.

Like Option A-2b, Option A-2c includes an Type 1 SBC at Lower Granite. This would include the construction of a full-length powerhouse SBC channel with dewatering to be used in conjunction with the existing ESBS system. At the lower three projects (Little Goose, Lower Monumental, and Ice Harbor dams) only ESBS intake diversion systems would be used. Since ESBS already exist at Little Goose, there would be no required modifications at this project, and the existing diversion/bypass facilities would continue to be used. At Lower Monumental and Ice Harbor dams, the existing STS intake diversion systems would be replaced with ESBS systems, but no additional SBC channels would be constructed to augment these systems.

If it is decided that transportation is the migration strategy for the river, Options A-2b and A-2c actually form a transportation package which could be initiated prior to a decision on which of the two combinations would constitute the final design. This is because everything involved in Option A-2c would be required in Option A-2b. In fact, the most prudent way to install Option A-2b would be to install Option A-2c first and test the SBC/ESBS collection facility at Lower Granite Dam. Any unanticipated bugs could then be worked out of the SBC design. If, after testing of Option A-2c, it is decided that Option A-2b is justified, lessons learned for the Type 1 SBC design at Lower Granite Dam could be applied at Little Goose and Lower Monumental dams.

Table 6-4 below summarizes the SBC types at each project which make up Option A-2c.

Table 6-4. Summary of SBC Option A-2c

System Combination No.	Lower Granite	Little Goose	Lower Monumental	Ice Harbor
Option A-2c: Transport (Low Cost) with Voluntary Spill at Ice Harbor only	Type 1 (Six-Unit Screened Channel)	None	None	None

6.7 Option A-2d: Major System Improvements—Adaptive Migration Strategy

6.7.1 General

Option A-2d assumes that the juvenile fishway systems will be operated in a manner that will balance the passage of fish between in-river and transport fish passage methods. The Adaptive Migration Strategy would optimize current operational objectives where either in-river or transport strategies can be used. This strategy addresses concerns about the risks and effectiveness associated with bypass-only and transport-only. Because of its design, this option would have the flexibility to allow operational changes to be made within a migration season if necessary.

This is similar to the fish passage strategy included for the Existing System Upgrade Adaptive Migration Strategy (Option A-1). See paragraph 5.4 for details.

Option A-2d includes 527 million cubic meters (427,000 acre-feet) of flow augmentation from upstream storage.

Actions required to implement Option A-2d are identified in the following sections. Refer to Annex B for a more detailed discussion.

6.7.2 Existing System Upgrades

Existing System Upgrade measures included with Option A-1, as described in paragraph 5.4, would be included with Option A-2d.

6.7.3 SBC

The migration strategy for Option A-2d allows for either fish-friendly transportation or in-river migration. At Lower Granite and Lower Monumental dams, Type 3 SBC systems would be installed in front of Turbine Units 5 and 6. These two-unit SBC channels would have two side-by-side entrances. One entrance would pass the fish through a dewatering section so that they could be delivered into the existing juvenile bypass channel, and ultimately to the transportation facilities, similar to the SBC channels in Options A-2b and c. The other entrance would not contain dewatering screens and would pass the fish directly to the tailrace and over a raised spillbay, similar to the SBC channels in Option A-6a. Therefore, fish collected by the SBC could be transported or bypassed. To guide fish away from Units 1 through 4, a BGS would be constructed in the forebay.

As with the other system options, ESBS intake diversion systems would be used in conjunction with these two-unit SBC channels. At Lower Granite Dam, the existing ESBS would be used, whereas at Lower Monumental Dam there would have to be new ESBS to replace the existing STS. ESBS would be located in the turbine intakes of all six units of both powerhouses to bypass fish that pass around or under the BGS.

At Little Goose Dam, a Type 2 SBC system would be installed. The Type 2 system consists of a full-length powerhouse SBC channel without dewatering. It would collect and pass fish directly to the tailrace. A Type 3 SBC system was not used at Little Goose Dam because a BGS would block navigation. Also, each turbine unit at Little Goose Dam would have an existing ESBS in place.

At Ice Harbor, a Type 4 SBC system would be constructed at the spillbay closest to the powerhouse. A BGS would extend upstream from the interface of the powerhouse and spillway. A removable raised spillway weir would be placed on the spillbay adjacent to the powerhouse to provide a more fish-friendly bypass over the spillway. New ESBS would replace the existing STS at Ice Harbor. They would be installed in the turbine intakes to offer a bypass for fish passing around or under the BGS.

Table 6-5 summarizes the SBC types for Option A-2d.

Table 6-5. Summary of SBC Option A-2d

System Combination No.	Lower Granite	Little Goose	Lower Monumental	Ice Harbor
Options A-2d:	Type 3	Type 2	Type 3	Type 4
Adaptive Migration Strategy	(Two-Unit Dual Bypass / Screened Channel with BGS)	(Bypass Channel)	(Two-Unit Dual Bypass / Screened Channel with BGS)	(Removable Spillbay Weir with BGS)

6.7.4 Voluntary Spill

Voluntary spill would be needed only at Ice Harbor Dam to aid in bypassing fish over the spillway when the river system is operating in a transport mode.

When the river system is operating in a bypass mode, the Type 3 surface collector specified for Lower Granite and Lower Monumental, as well as the Type 2 surface collector specified for Little Goose, have collection efficiencies low enough to justify having voluntary spill at these dams. Reference Section 4.4.4 for more information. However, when the river system is operating in a bypass mode, there would be no need for voluntary spill at Ice Harbor since the BGS is expected to divert about 78 percent of the fish away from the powerhouse, towards the spillway. Refer to Section 4.4.4 for more information on BGS performance. Therefore, when the river system is operating in a bypass mode, voluntary spill would occur at all dams except Ice Harbor.

7. Impacts to Hydropower

7.1 General

As discussed in Section 1.4, the Corps is currently required to spill at all lower Snake River dams to attempt to achieve an FPE target of 80 percent. Also, voluntary spill is assumed for some of the Upgraded Existing System options and Major System Improvement options. Voluntary spill results in less water available for hydropower production.

Use of SBC options also requires water to be passed over the spillway. This results in lost hydropower as well.

Each transportation option (Options A-2a, A-2b, and A-2c) assumes substantially reduced or eliminated voluntary spill, resulting in reduced hydropower losses. When compared to the current operating procedure, which includes voluntary spill, the loss of hydropower due to the use of surface collectors for fish transportation (Options A-2a and A-2c) is offset partially or completely by the reduced voluntary spill. For instance, Option A-2c utilizes one 170 m^3/s (6000 kcfs) surface collector that reduces hydropower economic benefits by about $4.5 million per year. However, hydropower benefits are increased by about $9.6 million per year over the current operating procedure due to the elimination of voluntary spill at Lower Granite, Little Goose, and Lower Monumental dams. The net effect for Option A-2c is an increase in hydropower economic benefits of $5.1 million over the current operating procedure (reference: “Technical Report on Hydropower Costs and Benefits”, developed by the Drawdown Regional Economic Workgroup: Hydropower Impact Team).

It is likely that a pumpback system or turbine generator could be installed to recoup most of the hydropower benefits that would otherwise be lost due to use of an SBC. Such a system would likely require an SBC with a dewatering system to separate the fish from the water that is either pumped back into the reservoir or passed through a turbine generator. The in-river passage options (Options A-6a, A-6b, and A-6d) do not have SBC dewatering systems. These options would likely have to be reconfigured to include SBC dewatering if pumpback systems or turbine generators were included. If any option using an SBC were selected for implementation, more detailed investigation of an energy conservation system would be required.

7.2 Voluntary Spill Caps

Table 7-1 summarizes existing and new projected voluntary spill caps as they currently are operated and illustrates how they could be operated in the future if gas abatement measures associated with upgraded existing systems were implemented. This includes additional end-bay deflectors and modification of existing deflectors. New gas abatement measures used with current flow levels would result in TDG supersaturation levels of about 112 percent to 115 percent. Alternatively, new gas abatement measures would allow a higher amount of flow without exceeding the limit of 120 percent TDG supersaturation. However, increased spill would reduce hydropower benefits. The lost hydropower benefits due to current and potential increased spill flows has not been determined. Spill flows are summarized for the two spill conditions, assuming spill to the 120 percent TDG supersaturation limit.

Table 7-1. Approximate Voluntary Spill Caps, Existing System and Existing System Upgrades

	Ice Harbor 1000 m^3/s (1000 cfs)	**Lower Monumental** 1000 m^3/s (1000 cfs)	**Little Goose** 1000 m^3/s (1000 cfs)	**Lower Granite** 1000 m^3/s (1000 cfs)
Existing System	3.11 (110)	1.2 (43)	1.4 (48)	1.3 (45)
Existing System Upgrades*	3.11 (110)	1.9 (68)	1.9 (68)	1.9 (68)

* Includes additional endbay deflectors and modified deflectors where appropriate.
Note: Voluntary spills based on 120 percent TDG supersaturation limit.

8. Unresolved Issues

8.1 General

Included below is a description of unresolved issues concerning dissolved gas abatement measures, turbine modifications, and SBC technology development. Resolution of these issues could impact the implementation schedules and costs included in this appendix.

8.2 Dissolved Gas Abatement Measures

8.2.1 General

The impacts of any spillway modifications on juvenile and adult fish passage, navigation and channel erosion must be considered. The addition or modification of spillway flow deflectors may potentially affect any or all of these items. In addition, as discussed in paragraph 4.2.1, there are still uncertainties associated with the ongoing Phase II DGAS studies.

There are other gas abatement measures not included in any of the Existing System or Major System Improvement options, but which are included in Annex C. These measures hold potential for significantly reducing TDG production. The engineering evaluation of these options is nearing completion. However, biological evaluations have yet to be completed. Thus, final recommendations regarding implementation of these specific measures will not be made until the system-wide analysis is completed over the next 1 to 2 years.

8.2.2 Adult Fish Passage

Model studies and prototype evaluations have shown deflectors in the outside spillway bays may create strong cross-currents (or lateral flows) immediately downstream of the adult fishway entrances. Tailrace conditions altered by additional deflectors may disorient and delay adult fish seeking passage through the fishway entrances adjacent to the spillways.

The effect of additional or modified flow deflectors on adult passage must be evaluated on a project-by-project basis, accounting for differences in project configurations, such as relative location of fishway entrances, channel bathymetry, and the existence of guide walls separating the entrances from the spillway stilling basin. Hydraulic model studies would be required. Modifications to the existing deflectors at Lower Granite Dam are not expected to affect adult fish passage.

If model studies indicate potential problems, it is anticipated that physical changes such as training wall extensions or changes in the deflector design would resolve the problem. Also, spillway operational changes resulting in modified spill patterns could be implemented. It is worth noting that similar spillway modifications have been installed at Ice Harbor and John Day dams without any apparent serious impacts to adult fish migration.

8.2.2.1 Lower Monumental Dam

Although not anticipated, if end-bay deflectors were to cause adult fish passage delays, discharge through these bays could be restricted during daylight hours with no impact to adults. These bays then could be operated throughout the night for additional gas reduction benefits.

8.2.2.2 Little Goose Dam

Conventional type deflectors in Spillway Bays 1 and 8 should have minimal impacts on adult fish passage.

8.2.3 Juvenile Fish Passage

The hydraulic flow conditions generated by deflected spill flow may directly impact survivability of juvenile salmonids migrating downstream. Increased turbulence in the vicinity of stilling basin baffle blocks and the end sill may increase with additional or modified deflectors. Increased turbulence in the vicinity of these structures may result in increased mechanical injury. Though many of the projects are similar, the influence of spillway modifications on juvenile fish passage must be evaluated on a project-by-project basis.

If problems are discovered, then changes to spillway operations resulting in modified spill patterns could be implemented to minimize impacts to juvenile fish.

8.2.4 Navigation

Flow deflectors decrease the amount of energy dissipated within the stilling basin, increasing the velocity of flow in the downstream channel. The extent that deflectors influence navigation conditions downstream of the lock entrances depends on the channel configuration, bathymetry, and the relative location of the navigation lock to the spillway. Increased velocity and cross-channel flows may make it difficult for tow operators to maintain proper alignment and speed as they approach and exit the downstream lock entrance. Potential impacts of additional or modified deflectors on navigation must also be evaluated on a project-by-project basis. Modifications to the existing deflectors at Lower Granite Dam are not expected to affect navigation.

8.2.4.1 Lower Monumental Dam

The navigation lock at Lower Monumental Dam is located near the south non-overflow embankment and is separated from the spillway by the south shore fish ladder. Surface skimming flow deflected from Spillway Bay 1 may increase channel velocities below the downstream lock entrance. Higher velocities could create problems for tows exiting and entering the downstream lock approach.

Hydraulic modeling would be used to determine the impacts of any spillway modifications. If problems are discovered, changes could be made to the spill patterns. Also, cellular cofferdams, similar to those at Ice Harbor Dam, could be installed, or the guide wall could be extended. This would provide a physical barrier to the spillway flows adjacent to the downstream approach to the lock.

8.2.4.2 Little Goose Dam

Conventional type deflectors in Spillway Bays 1 and 8 and existing deflector modifications at Little Goose Dam should have no adverse impacts on navigation. The peninsula downstream of the dam provides a suitable barrier to the spillway flows.

8.2.5 Stilling Basin and Channel Erosion

The ability of the spillway and stilling basin to adequately dissipate the energy of spillway design flows must not be compromised by any spillway modifications. If the primary energy from the spillway can be contained within the stilling basin, no damage will occur to the structure. Model studies show the standard 3.8-meter (12.5-foot) long flow deflectors at Lower Monumental and Lower Granite dams will not cause a hydraulic jump to occur downstream of the stilling basin, regardless of the flow rate. However, standard length deflectors at Little Goose Dam may cause problems with energy dissipation because of the roller bucket.

8.2.5.1 Lower Monumental Dam

Due to erosion, large holes have been created in the Lower Monumental stilling basin since the construction of flow deflectors in the center six spillway bays. The erosion has occurred near the toe of the spillway below Spillway Bays 1 and 2 and 7 and 8. Because of the location of the holes it is believed that the erosion has been caused by hydraulic conditions created by the interaction of deflected and non-deflected spillway flows. Adding flow deflectors to Spillway Bays 1 and 8 may reduce the potential for continued erosion. However, due to the severity of the problem, stilling basin conditions must be thoroughly investigated before a recommendation of additional deflectors can be made.

8.2.5.2 Little Goose Dam

Extending the existing deflector lengths to 3.8 meters (12.5-feet) may result in insufficient energy dissipation of the project design flows, forcing the hydraulic jump and high-energy flow into the downstream channel and potentially causing erosion of the downstream channel and shoreline. Likewise, adding similar size deflectors to the end bays may also compromise the roller bucket’s ability to dissipate the energy of high spillway flows and may increase the potential for tailrace channel erosion. Model studies will be needed to assess the potential impact.

8.3 Turbine Measures

Unless natural river drawdown is selected, it is likely that all of the generating units will require major repair or rehabilitation in the next 10 to 50 years. Now, the exact nature of turbine related modifications and associated fish benefits are not specifically known. However, benefits to anadromous fish stocks are potentially significant since they will accrue over the life of a rehabilitated turbine, estimated to be 35 to 50 years. The current Turbine Passage Survival Program is yielding information to allow an accurate evaluation of fish passage benefits associated with turbine operational changes and modifications. This evaluation is expected to be complete in about 10 years.

8.4 SBC Measures

8.4.1 SBC Performance

Present SBC performance numbers are based on SBC prototype testing conducted at Lower Granite Dam between 1996 and 1998. (See Section 4.4.4). In the case of SWI and BGS components of SBC, these features have undergone just one year of testing. Given the nature of the prototype tests and the limited test duration, predictions of how SBC systems might perform for full-system designs at Lower Granite Dam and other lower Snake River projects can only be projected. However, it is believed that prototype type test results thus far do provide a conservative prediction of how full-scale production systems would perform. It is believed that with continued SBC research and development there is a high likelihood that significant gains in SBC fishway performance can still be realized.

8.4.2 Dewatering

Several of the current options for SBC development (see Sections 4.4.3 and 4.4.5) would require the use of large-scale dewatering systems that would be substantially larger than any screen system used on any project to date. Large-scale dewatering systems discussed in this report are needed for all transport-related options. In-river options do not have dewatering. In-river designs, however, may also eventually require dewatering if some form of sampling and fish tag evaluations is ever required, or if it is desired to reduce large fish attraction flows down to an amount that can be economically handled.

The original study plan for dewatering was to perform field investigations, conduct literature searches, develop design criteria, concept designs, complete large scale hydraulic model studies, and design, construct, and test a prototype dewatering structure in conjunction with a SBC prototype. Progress was made on all of these items, except for detailed design, construction, and testing of a dewatering prototype structure. For a variety of reasons, such as budgetary constraints, design criteria uncertainties, uncertainties as to how well SBC technology would perform, and a general aversion by many to dewatering, the goal to complete a dewatering prototype test structure in time to provide input to the feasibility study was dropped.

A variety of critical issues have to be answered before large-scale dewatering can be used with a high degree of confidence. A physical hydraulic model study of a dewatering prototype test structure indicated that more progressive dewatering screen criteria with a specially shaped channel floor and sidewall design would be feasible from a hydraulics perspective. Since the model performed well hydraulically, the consensus is that it would likely perform well from a biological perspective. However, large scale dewatering, as it relates to biological performance and project operations/reliability concerns, can only be answered with certainty by evaluating the results from a prototype test structure. Until such a prototype structure is tested, which would also require additional detailed hydraulic modeling, uncertainties about large-scale dewatering will exist.

The final design criteria used for development of a permanent dewatering structure would be based upon the results of the prototype test.

8.4.3 Reduced Spillway Capacities

Some of the SBC options impacting existing spill bays reduce original spillway flow capacities by as much as 5 percent. For these options to be completed using these designs, approval will be required from a higher authority to reduce spill levels authorized for original projects. If approvals for reduced spill levels are not given, alternative plans involving higher cost designs could be used. Some alternative plans to address the reduced spillway capacity include the following:

- Routing SBC flows to the tailrace via modified portions of non-overflow sections of dams. Refer to the appendix at the end of Annex B for more information.
- Modifying some of the other spillbays to their increase spill capacity. This option would likely be very expensive.
- Passing excess flood flows through the turbines. Perforated bulkheads installed upstream and/or downstream of the turbines would be required to reduce the large head differential enough to avoid damaging the turbines. However, this option has not yet been studied in detail.
- Passing excess flood flows through the navigation lock culverts and into the lock, to exit downstream through the open downstream lock gate. However, this option has not yet been studied in detail.

8.4.4 Structural Design Issues Related to Modifications to Existing Spillways and Central Non-Overflow Sections

Additional seismic structural stress analysis of key existing structures would be required for some of the options due to the addition of SESs and RSWs to the spillway and central non-overflow monoliths. These analyses would be especially important at Ice Harbor Dam where design ground accelerations are high. A stability analysis of the spillway at Ice Harbor Dam would be required before attaching any structures to it. If the stability of any monolith is compromised, or concrete design stresses are found to be excessive, additional concrete and/or posttensioning may be added to bring the structure(s) into compliance with current design criteria.

8.4.5 Removable Spillway Weir

The removable spillway weir included with Type 4 SBC systems would require model testing to determine the best shape for development of a full-size prototype. Prototype testing would show whether an acceptable design could be developed that does not harm fish. Since the RSW would be resting on top of an existing spillbay, there are limitations on the possible shapes of the RSW. However, it is currently anticipated that a successful design could be developed.

8.5 Miscellaneous Measures

Some of the miscellaneous measures to upgrade present facilities, as discussed in Section 4.5, involve issues related to either uncertainties surrounding effectiveness of the improvement or its specific design layout.

Examples of features that are either being researched now or soon will be include cylindrical dewatering screens and modified fish separators. The results of the research and testing will determine if these items are to be implemented. Also, the results will be used in developing the final design of the upgrades to the Lower Granite Juvenile Fish Facilities. The decision on whether or not to install an SBC at Lower Granite Dam would also affect the design of the juvenile facility upgrade.

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9. Costs and Schedules

9.1 General

Costs and implementation schedules for each of the options evaluated in this appendix have been developed and are summarized in Tables 9-1, 9-2, and 9-3 and in Figure 9-1, contained herein. Included are costs for construction, operation, and maintenance, as well as other specific federal requirements for each of the options. The costs were developed as comparison type costs, for use in the economic studies and option selecting. Costs do not include escalation and are not intended to be used as program funding estimates. These costs are based on the scope of work, assumptions, and methodology presented in the "Detailed Project Schedule PB-2A" (PB-2A) and Engineering Annexes A through D of this appendix. Engineering, design and construction supervision, and administration costs are included in new construction costs. Also, all costs include contingencies. More detailed cost and implementation information can be found in Annex E. Final cost comparisons will take place in Technical Appendix I—Economics.

Costs are tabulated for each of the eight options for operating the four lower Snake River dams as shown in Table 9-1.

Table 9-1. Options Included in the Cost Estimates

Option Number	Existing System Upgrade or Major System Improvement	River Operational Strategy
A-1	Existing System Upgrade	Adaptive Management Strategy
A-1a	Existing System Upgrade	In-River Operation
A-2a	Existing System Upgrade	Maximizing Transport
A-2b	Major System Improvement	Maximizing Transport with SBC (high-cost option)
A-2c	Major System Improvement	Maximizing Transport with SBC (low-cost option)
A-2d	Major System Improvement	Adaptive Migration Strategy with SBC
A-6a and A-6b	Major System Improvement	In-River Passage with SBC and without BGS
A-6d	Major System Improvement	In-River Passage with BGS

9.2 Methodology for Development of Cost Estimates

This report includes concept level cost estimates. Estimates were developed for each of the nine options. Costs are developed based on a 100-year life cycle analysis. All costs are at a price level October 1, 1998 (start of the fiscal year). For comparison purposes, no allowance is included for inflation to cover construction time. All costs are shown as present-worth fiscal year 1998 costs. A period extending from 2001 to 2045 is included in the graphs. After 2045, annual costs are fairly constant.

Construction and acquisition costs are present-worth values, based on PB-2A, conceptual design reports, and supporting documents. These budgetary costs include costs for contracts, construction, prototypes, testing and development, feasibility studies, real estate, cultural resources, engineering and design, construction management, and project management. It has been assumed for cost development that fish passage around the dams will not be impacted during construction. Therefore, in-water construction work will be allowed only during normal in-water work windows. Other assumptions and costs are documented in the annexes. The cost for construction and acquisition occur for a short period during these economic studies.

Anadromous fish evaluation program annual costs are for testing, research, development, and evaluation of the effects of dam improvements on migrating fish. These study-costs occur for approximately the first 25 years of the construction and rehabilitation improvements.

Operations and maintenance annual costs are based on historical records received from Programs Management Branch within the Corps. They are tabulated and broken out per work breakdown structure and separated into operations and maintenance costs for each dam. Minor and major rehabilitation costs, such as costs for navigation locks, spillways, and miscellaneous costs, are included in the O&M cost data. However, costs for major rehabilitation of the powerhouse are not included with operations and maintenance costs.

Costs for minor repair are shown as an annual cost based upon an assumed percentage of operation and maintenance costs. An additional percentage was used to cover the cost of aging equipment. When minor repairs and routine operation and maintenance costs are combined, the result is the complete cost of operating and maintaining the four lower Snake River dams, except for major rehabilitation of the dam turbine and generator units. Routine operation, maintenance, and minor repair costs are included for the full duration of the economic study.

Major rehabilitation costs are present worth costs for completely rehabilitating all 24 turbine and generator units at the lower Snake River dams. This includes rehabilitation of the turbines, the turbine blades (six blades per turbine), rewinding generators, and miscellaneous work. Because of the time spanned by the economic study, more than one rehabilitation will be required. The second group of turbine rehabilitations is not shown in the table or on the graphs because they would occur very far in the future, but the second group of rehabilitation costs is included in the economic studies report. These major repair and rehabilitation costs are assumed to occur during various short periods within the economic study life.

Fish hatchery annual costs are for operating, repairing, and rehabilitating the fish hatcheries. The costs for operating and maintaining the fish hatcheries are assumed to occur for the full duration of the economic study.

Bureau of Reclamation (BOR) water acquisition annual costs include obtaining additional water for flow augmentation to aid downstream migrating fish. Average costs for water acquisition were used in the development of these costs. The water is purchased from natural (irrigator) flow rights, changes in lower Snake River reservoir operations, and additional water from BOR storage reservoirs. These water purchase costs occur for the full duration of the economic study.

9.3 Uncertainties

The yearly costs funding profile graphs show the funds needed to accomplish the work on schedule (without inflation). However, final schedules and project costs depend upon funding limitations and will be adjusted accordingly. The schedules assume that work will start in FY 2001 (Oct 1, 2000).

Because various aspects of the fish mitigation program are in the early stages of development, certain requirements may change and costs may vary. There were no additional costs included for future improvements to the existing fish facilities that may occur upon completion of research.

The 24 lower Snake River dam turbine units have an approximate life span of 35 to 50 years. It is assumed that approximately 10 years is required to rehabilitate the six turbine units at each dam, and only one turbine unit can be rehabilitated at a time, in order to maintain consistent power production. Also, it is assumed that rehabilitation will occur at just one dam at a time due to anticipated funding limitations. The schedule assumes the final turbine unit rehabilitation at each dam will be completed 10 years after the end of its estimated 50-year life span (see schedule). This method is a conservative approach to rehabilitation of the turbine units.

Schedules, concept costs, and the fish mitigation program are under development and are subject to change as direction and funding are made available. All annual costs are an approximation of fluctuating costs and funding and are subject to change over time.

9.4 Summary Tables and Graphs

Tables 9-2 and 9-3 and Figure 9-1 provide a summary of costs and implementation schedules for each of the options described in Section 9.1. More detailed information is available in Annex E.

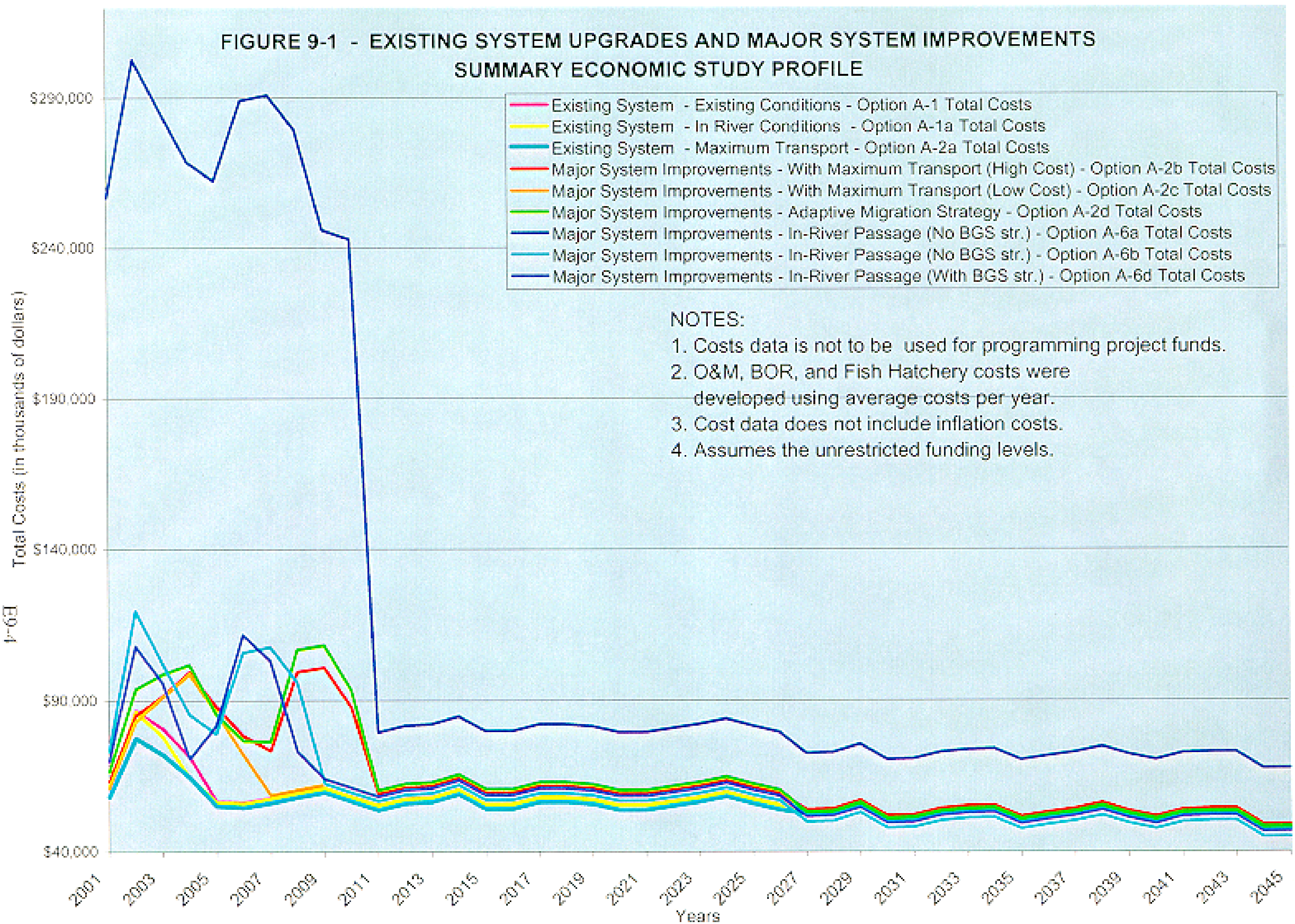
FIGURE 9-1 - EXISTING SYSTEM UPGRADES AND MAJOR SYSTEM IMPROVEMENTS
SUMMARY ECONOMIC STUDY PROFILE
Existing System - Existing Conditions - Option A-1 Total Costs
Existing System - In River Conditions - Option A-1a Total Costs
Existing System - Maximum Transport - Option A-2a Total Costs
Major System Improvements - With Maximum Transport (High Cost) - Option A-2b Total Costs
Major System Improvements - With Maximum Transport (Low Cost) - Option A-2c Total Costs
Major System Improvements - Adaptive Migration Strategy - Option A-2d Total Costs
Major System Improvements - In-River Passage (No BGS str.) - Option A-6a Total Costs
Major System Improvements - In-River Passage (No BGS str.) - Option A-6b Total Costs
Major System Improvements - In-River Passage (With BGS str.) - Option A-6d Total Costs
NOTES:
1. Costs data is not to be used for programming project funds.
2. O&M, BOR, and Fish Hatchery costs were developed using average costs per year.
3. Cost data does not include inflation costs.
4. Assumes the unrestricted funding levels.
Total Costs (in thousands of dollars)
$290,000
$240,000
$190,000
$140,000
$90,000
$40,000
2001
2003
2005
2007
2009
2011
2013
2015
2017
2019
2021
2023
2025
2027
2029
2031
2033
2035
2037
2039
2041
2043
2045
Years

Table 9-2. Summary Table of Costs and Implementation Schedules for Existing System Upgrade Options

Option No./ Description (Spill Condition)	Construction Costs ($million)	Construction Implementation Schedule (Duration–Years)	Anadromous Fish Evaluation Program (AFEP) annual costs for 27 years ($million)	AFEP Implementation Schedule (Duration–Years)	Routine O & M and Minor Annual Repair ($million)	Major Rehabilitation of Turbines ($million)	Major Rehabilitation of Turbines Implementation Schedule (Duration–Years)	BOR Annual Costs ($million)
Existing System Upgrades								
A-1 Adaptive Management Strategy (Voluntary Spill)	89.3	5	5.3	27	30.7	193.6	41	2.3
A-1a In-River (Voluntary Spill)	80.1	5	5.3	27	30.5	193.6	41	2.3
A-2a Transport (No Voluntary Spill except Ice Harbor)	67.9	5	3.6	27	30.7	193.6	41	2.3

Table 9-3. Summary Table of Costs and Implementation Schedules for Major System Improvement Options

Option No./ Description (Spill Condition)	Construction Costs ($million)	Construction Implementation Schedule (Duration–Years)	Anadromous Fish Evaluation Program (AFEP) annual costs for 25 years ($million)	AFEP Implementation Schedule (Duration–Years)	Routine O & M and Minor Annual Repair ($million)	Major Rehabilitation of Turbines ($million)	Major Rehabilitation of Turbines Implementation Schedule (Duration–Years)	BOR COSTS ($million)
Major System Improvements								
A-2b Transport (High cost–no voluntary spill)	270.0	11	7.4	27	32.2	193.6	41	2.3
A-2c Transport (Low Cost–No Voluntary spill except Ice Harbor)	162.5	7	5.7	27	31.3	193.6	41	2.3
A-2d Adaptive Management Strategy (Voluntary spill varies)	297.3	11	9.5	27	31.3	193.6	41	2.3
A-6a In-River (Voluntary spill and no BGS, higher flow augmentation)	316.7	10	9.2	27	30.3	193.6	41	22.8 annual cost plus $160.5 for first 10 years
A-6b In-River (Voluntary spill and no BGS, no flow augmentation)	316.7	10	9.2	27	30.3	193.6	41	2.3
A-6d In-River (Voluntary spill only at Little Goose, BGS at other dams)	249.2	10	9.0	27	29.9	193.6	41	2.3

10. Glossary

3-D cams: Computer software based upon the turbine performance curves that automatically adjusts the wicket gate openings and turbine blade angle to optimize turbine efficiency.

Adaptive Migration Strategy: This strategy allows for the use of either in-river bypass and/or transportation of juvenile fish.

Anadromous Fish Evaluation Program (AFEP): Involves biological evaluations of anadromous fish and evaluations of proposed dam modifications to predict resulting impacts to fish.

Anadromous Fish: Fish, such as salmon or steelhead trout, that hatch in fresh water, migrate to and mature in the ocean, and return to fresh water as adults to spawn.

Behavioral guidance structure (BGS): Long, steel, floating structure designed to simulate the natural shoreline and guide fish toward the surface bypass collection system by taking advantage of their natural tendency to follow the shore.

Collection channel: A channel within the powerhouse that downstream migrating fish enter after being guided away from the turbines with turbine intake screens or a surface collector. The fish travel down the channel to a juvenile fish facility where they are transported downstream of Bonneville dam.

Combined bypass efficiency (CBE): Refers to the total number of fish guided by the screens or collected by a surface collector, as a percentage of the total number of fish approaching the powerhouse.

Cylindrical dewatering screens: A structure used for reducing the flow of water to the juvenile fish facilities. Cylindrical dewatering screens may be an improvement over existing dewatering screens, but need to be tested using a prototype before implementation.

Dewatering: The process of removing excess water from a surface collector or the juvenile fish collection system in order to have reduced flow that the juvenile fish facilities can handle.

Dissolved gas supersaturation: Caused when water passing through a dam's spillway carries trapped air deep into the waters of the plunge pool, increasing pressure and causing the air to dissolve into the water. Deep in the pool, the water is "supersaturated" with dissolved gas compared to the conditions at the water's surface.

Existing System Upgrades: Changes implemented to improve the effectiveness of the current fish collection/bypass facilities.

Existing System: The existing hydrosystem operations under the National Marine Fisheries Service's 1995 and 1998 Biological Opinions. The Corps would continue to increase spill and manipulate spring and summer river flows as much as possible to assist juvenile salmon and steelhead migration. Juvenile salmon and steelhead would continue to pass the dams through the turbines, over spillway, or through the fish bypass systems. Transportation of juvenile fish via barge or truck would continue at its current level.

Extended submerged bar screens (ESBS): Screens extending in front of the turbines to guide fish away from the turbines, up to the juvenile fish collection channel inside the dam. These are an alternative to submerged traveling screens.

Fish collection/handling facility: Holding area where juvenile salmon and steelhead are separated from adult fish and debris by a separator and then passed to holding ponds or raceways until they are loaded onto juvenile fish transportation barges or trucks.

Fish guidance efficiency (FGE): Percent of juvenile salmon and steelhead diverted away from the turbines by submerged screens or other structures.

Fish Hatcheries: Hatcheries operated to compensate for reduced numbers of anadromous fish.

Fish Ladder: A structure designed to provide safe adult fish passage from the downstream to the upstream side of each dam.

Fish passage efficiency (FPE): Portion of all juvenile salmon and steelhead passing a facility that do not pass through the turbines.

Fish Separators: Structures that separate juvenile salmon from juvenile steelhead.

Flow Augmentation: Includes the use of upstream storage for flow augmentation. Flow augmentation decreases the duration of downstream migration of juvenile fish.

In-River Bypass: Operations that bypass fish directly to the tailrace via existing spillways or through some type of fish bypass system.

Involuntary Spill: Spill that is required to pass high river discharge past the project once powerhouse capacities/owner requirements have been reached.

Juvenile fish transportation system: System of barges and trucks used to transport juvenile salmon and steelhead from the lower Snake River or McNary dam downstream of Bonneville dam for release back into the river.

Minimum Operating Pool (MOP): The bottom one foot of the operating range for each reservoir. The reservoirs normally have a 3-foot to 5-foot operating range.

Removable spillway weir (RSW): A removable steel ogee-shaped structure that is inserted into the existing spillbay, creating a raised overflow weir above the existing concrete ogee crest. The weir is used to aid in bypassing fish over the spillway.

Simulated Wells insert (SWI): Modified turbine intake that draws water from below the surface so that the surface is calmer and juvenile fish are less influenced by turbine flows. This allows juvenile fish more opportunity to discover and enter the SBC.

Spill Operations: Includes voluntary spill to assist in the bypassing of juvenile salmon and steelhead over the dam spillways. The spill is thought to attract the fish away from the turbines, and towards the spillway.

Spillway deflectors: Structures that limit the plunge depth of water over the dam spillway, producing a less forceful, more horizontal spill. These structures reduce the amount of dissolved gas trapped in the spilled water.

Spillway extension structure (SES): A structure attached to the upstream face of the spillway to aid in passing water from the surface collector over the spillway.

Submerged traveling screens(STS): Structures with a moving (travelling) screen extending in front of the turbines to guide fish away from the turbines, up to the juvenile fish collection channel inside the dam. These are an alternative to extended submerged bar screens.

Surface bypass collection (SBC) system: Structures designed to divert fish at the surface before they dive and encounter the existing turbine intake screens. SBCs collect the juvenile fish and guide them downstream, either over the dam spillway or to the juvenile fish transportation system.

Transport: Directing fish to a truck or barge transport system with capabilities to bypass fish to the tailrace in an emergency.

Trash Boom: A floating structure in front of the dam to collect floating debris. The trash boom prevents trash from getting into the juvenile fish collection system and causing damage to fish, clogging of screens, etc.

Voluntary Spill: Bypassing water over the spillway intended to attract juvenile fish to the spillways for in-river passage.